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UNITED STATES ATOMIC ENERGY COMMISSION

GRAND JUNCTION OPERATIONS OFFICE

EXPLORATION DIVISION

GEOLOGIC STUDIES AND DIAMOND DRILLING IN THE EAST CARRIZO AREA, APACHE COUNTY, ARIZONA, AND SAN JUAN COUNTY, NEW MEXICO

CONTRACT NO. AT(30-1)-1260

by

John A. Masters, Kenneth G. Hatfield, N. James Clinton,
Robert E. Dickson, C. Richard Maise,
and Lewis Roberts

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From : Ernest R. Gordon, Director
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GEOLOGIC STUDIES AND DIAMOND DRILLING
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ABSTRACT

Drilling in the East Carrizo area of northeastern Arizona and northwestern New Mexico disclosed many small uranium-vanadium orebodies in the lower part of the Salt Wash member of the Morrison formation. It is suggested that the deposits are controlled by lateral stratigraphic changes in sandstone beds and were precipitated from ore solutions moving with ground water along permeable courses in sandstone beds. The solutions appear to have been dammed by zones of low permeability and the ore precipitated by organic material. The deposits are generally elongate parallel to the channels.

The passage of ore solutions apparently altered the color of mudstones and sandstones from red to gray. "Alteration colors" are considered indicative of favorable areas. Higher than normal radioactivity of the sandstone is also a guide to favorable areas. Subsurface geologic maps designed to show "alteration colors" and radioactivity served as drilling guides.

INTRODUCTION

In the first half of 1952, the Atomic Energy Commission diamond drilled the East Carrizo area to locate uranium ore and to encourage production. Diamond drilling began in February, 1952, under contract AT(30-1)-1260 with the Minerals Engineering Company, Grand Junction, Colorado, and was completed in August, 1952. Drilling totaled 100,038 feet in 948 holes. The Salt Wash member of the Morrison formation, which contains all the known ore deposits in the region, received the most attention.

Location

The East Carrizo area lies across the Arizona-New Mexico line, between 16 and 20 miles south of the common corner of Arizona, Utah, Colorado, and New Mexico. Its location is given in two public land surveys: T. 11 N., R. 5 W., Navajo meridian, New Mexico, and T. 39 N., R. 31 E., Gila and Salt River meridian, Arizona. This area is accessible via U. S. Highway 666 to a point six miles south of Shiprock, New Mexico, thence west 20 miles over an improved dirt road to the Red Rock Trading Post and thence 10 miles north (fig. 1).

Physiography

South of the East Carrizo area a plain of low relief extends nearly 20 miles to the Chuska Mountains. The east margin of the plain is broken by a row of Dakota sandstone-capped hills rising 700 feet above the drilling area. Red Rock Wash flows northward through the hills, and drains all of

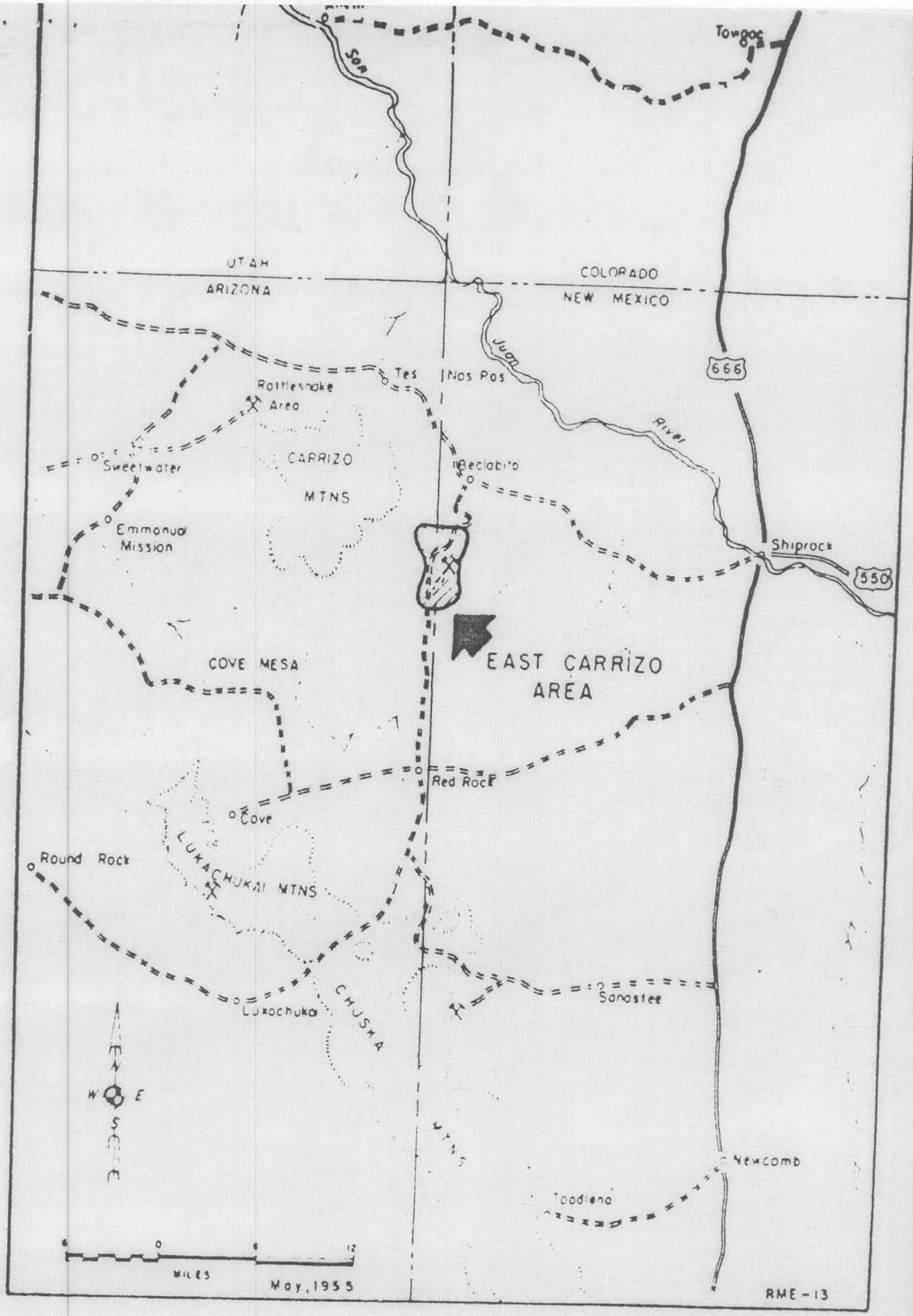


Figure 1. Location East Carrizo area, Arizona — New Mexico

the territory between the Carrizo Mountains and Shiprock. To the north, many small washes dissect the surface; the cliffs thus formed may attain heights of 150 feet. Though the relief is not great, much of the terrain is quite rugged. The altitude of the area drilled ranges from 5,500 to 6,000 feet.

The drill area includes King Tutt Mesa and the Oak Springs area (fig. 2). King Tutt Mesa, bounded on the south and east by Red Rock Wash and on the north by Oak Springs Wash, is capped by Salt Wash sandstone dipping 2 degrees east. The mesa is roughly elliptical, 1½ miles long and 1 mile wide.

The Oak Springs area is between Oak Springs Wash and Cottonwood Wash 3 miles farther north. Unlike the nearly flat King Tutt Mesa, the Oak Springs area is dissected by numerous small washes separated by ridges with ledgy slopes. Six miles west of the Carrizo Mountains, a gravel-surfaced pediment projects into the area.

Method of Investigation

On King Tutt Mesa the space between diamond drill holes was successively reduced in order to determine the maximum spacing at which the correlation of the core logs was reliable. Primary grid ore holes were offset 25 to 50 feet in order to outline the orebody. At the same time, development drilling behind mineralized outcrops was in progress.

The Oak Springs area was drilled on approximately 1,000-foot spacing. All cores were logged, and each hole was gamma-ray logged by a Batskoy unit. Supplementary stratigraphic data were obtained from sections measured at the outcrops.

Following the suggestions of W. L. Stokes and D. J. Jones, cross-bedding and sedimentary lineation were plotted to determine the directional trends of stream deposits. Structure on the Salt Wash-Bluff contact was mapped by plane table and from drill-hole information. An experimental program to measure the electrical resistivity of the Salt Wash sandstone was also carried on. This work and its results have been described in a paper by the Bureau of Reclamation 1/.

Previous Work and Acknowledgments

The best description of the general geology of northeastern Arizona is given by H. E. Gregory 2/. The ore deposits were first described by A. H. Coleman 3/. In 1951, the U. S. Geological Survey published a paper by W. L. Stokes 4/, who had studied the deposits as early as 1942. W. L. Stokes and D. J. Jones of the University of Utah gave assistance in the field. Space does not permit mention of all the Atomic Energy Commission geologists whose work has contributed to this report. Particular credit should be given to R. J. Garcia, R. L. Redmond, R. T. Zitting, G. E. Klosterman, C. D. Thompson, and P. V. Storm for their aid.

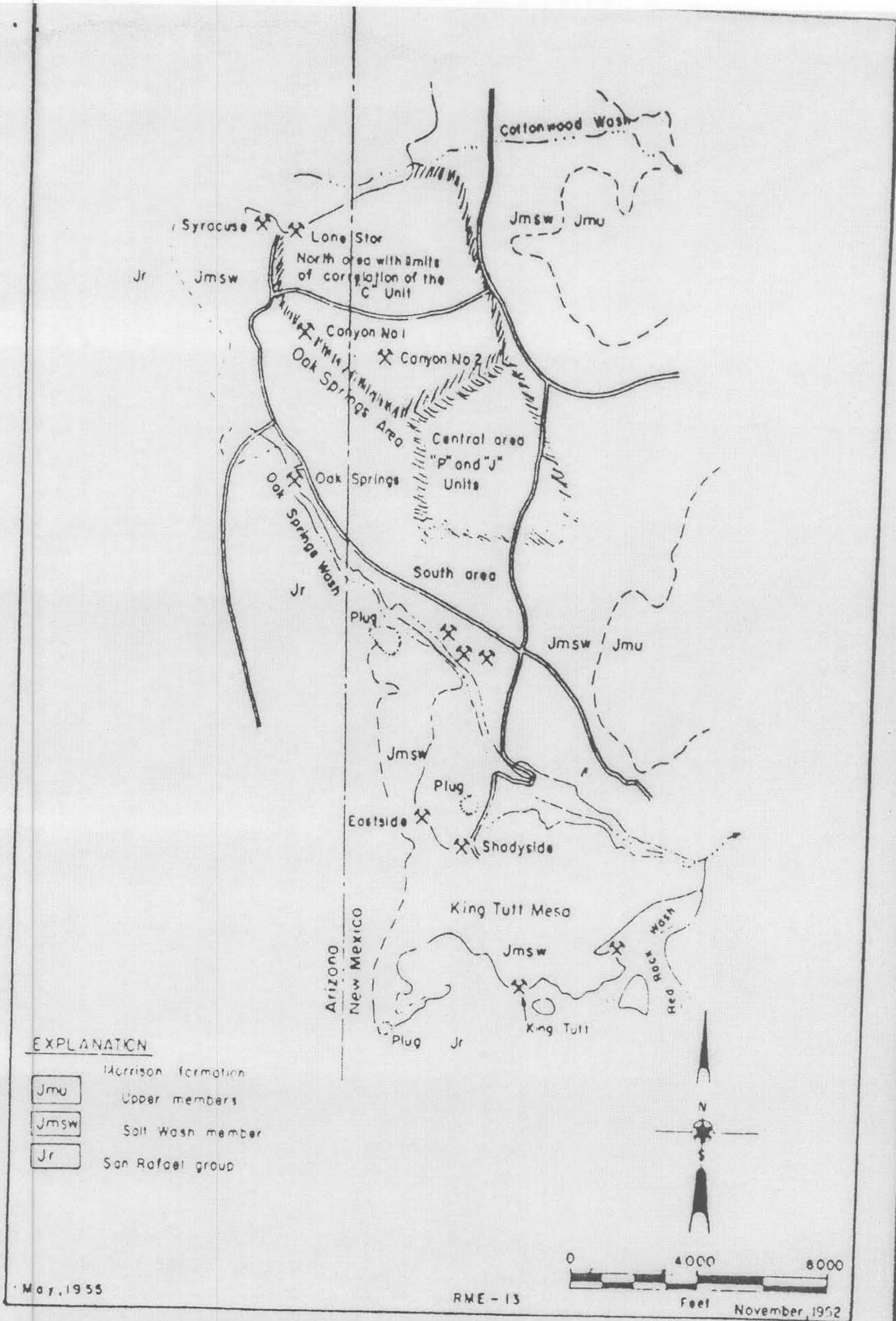


Figure 2. Geologic map of East Carrizo area, Arizona — New Mexico

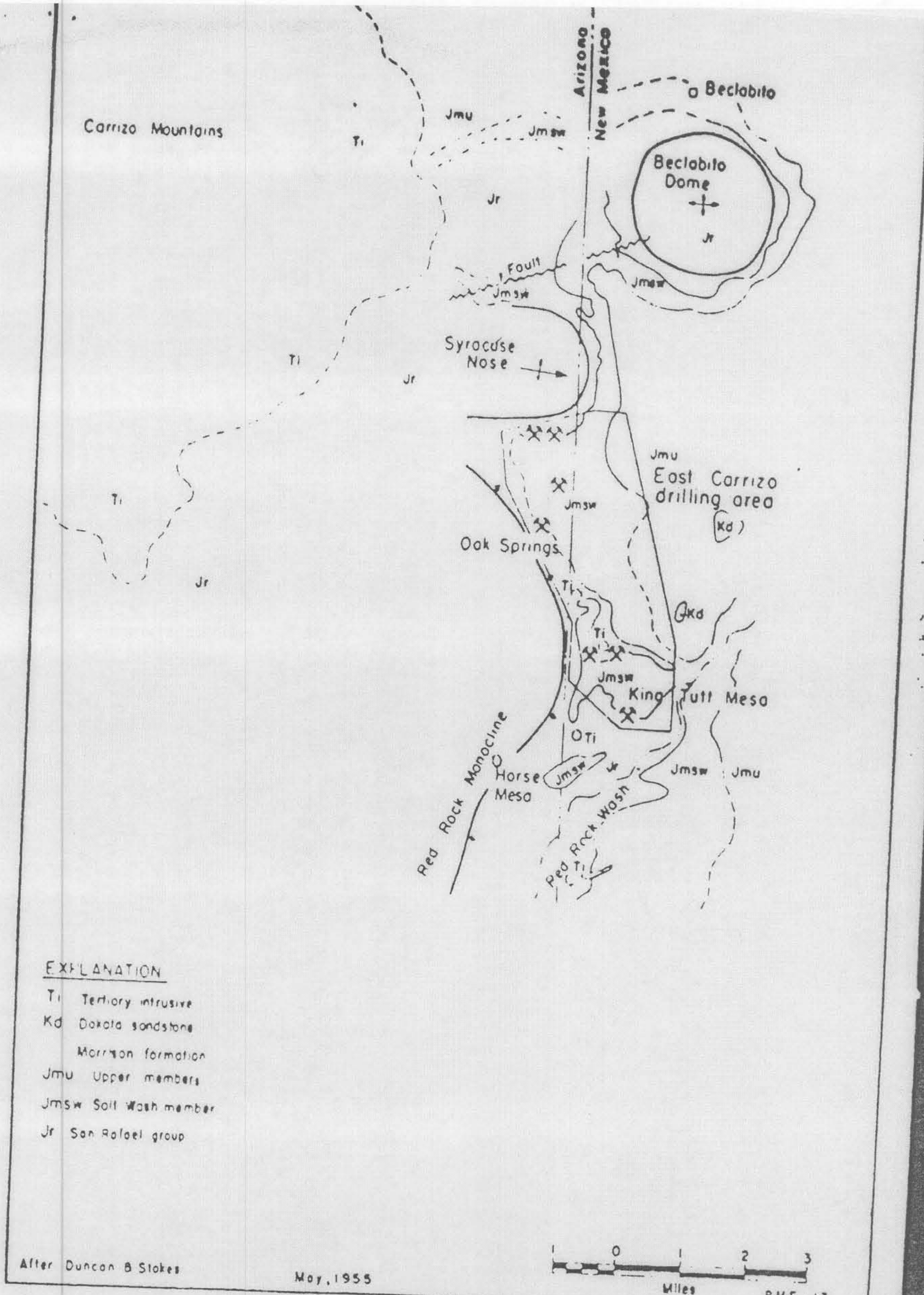


Figure 3. Regional geologic map, East Carrizo area, Arizona—New Mexico

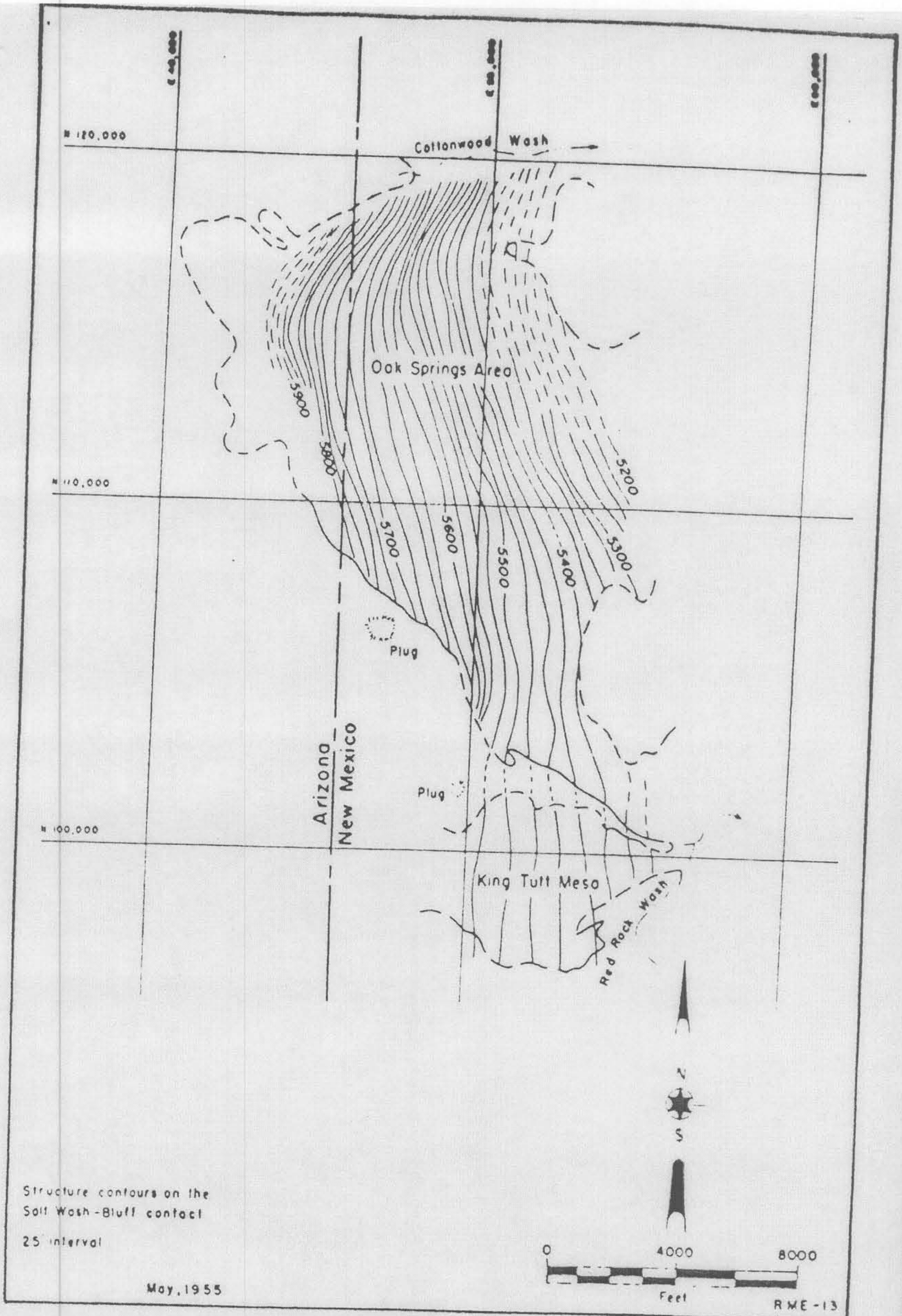


Figure 4 Structure contour map, East Carrizo area,
Arizona - New Mexico

History of Development

The first mining in the area was in 1918 for radium. From that date until 1948, mines operated intermittently for radium and vanadium, and since 1948, for uranium and vanadium.

Though all claims are held by Indians, most of the property is leased by the Vanadium Corporation of America, which has subleased many of the claims. J. W. Duncan and Climax Uranium Company also have contracts with Indian owners.

Several years ago, the Vanadium Corporation of America drilled several core holes behind some of the workings, but no logging records could be located.

GENERAL GEOLOGY

Structure

The East Carrizo area lies on the eastern flank of the laccolithic Carrizo Mountains (fig. 3). On the eastern border of the area, beds dip gently toward the San Juan Basin. Superimposed upon this dip are other and smaller structures. Red Rock monocline, dipping as much as 10° east, borders the western edge of King Tutt Mesa. This monocline can be traced 20 miles southward until its configuration is obscured by the horizontal Tertiary rocks of the Chuska Mountains. At King Tutt Mesa, Red Rock monocline curves eastward, then strikes northwesterly toward the northwestern corner of the drill area where it merges with the Syracuse structural nose. This latter feature plunges eastward away from the Carrizo laccolith. Both Stokes 4/ and King 5/ suggest that, prior to the intrusion of the Carrizo laccolith, Red Rock monocline may have been continuous with a monocline on the northwest side of the Carrizo Mountains, where the Rattlesnake mine is located.

The Salt Wash sandstone at King Tutt Mesa dips $1\frac{1}{2}^{\circ}$ east; in the Oak Springs area, the dip increases to about 3°. The beds strike north across King Tutt Mesa, swing northwest, and then strike northeast around the Syracuse nose (fig. 4). In the East Carrizo area, it is not apparent that structure has any control over ore deposition.

Stratigraphy

Table 1 outlines the stratigraphy of the area. Where details of lithology are pertinent to other features, they are discussed.

Table 1. - Stratigraphy of the East Carrizo Area

System	Formation and member	Thickness, feet	Description
Cretaceous	Dakota sandstone	30	Conglomerates and conglomeratic sandstone, white to grayish-pink; mostly quartz; pebbles up to 4" diameter.
	Burro Canyon formation(?)	100	Sandstone, orange, medium- to coarse-grained; claystone, gray to brown.
Jurassic	Morrison formation		
	Brushy Basin member	85	Siltstone, gray, green, and red;
	Westwater Canyon member	265	sandstones, mostly gray, fine- to coarse-grained, thick; claystones, thin, gray-green.
	Recapture member	190	Claystones, grayish-red; sandstones, light brown.
	Salt Wash member	220	Sandstone, light gray to light red, very fine- to medium-grained, cross-bedded, interbedded with claystones, calcareous cement; claystones, thin, mostly red.
	Bluff sandstone	15-20	Sandstone, light brown to orange, frosted quartz grains.
	Summerville formation (Silk Creek)	135	Sandstones, light red to chocolate brown, laminated, interbedded; fine-grained.
	Todilto limestone	0-3	Limestone, abundant disseminated quartz sand, light gray.
	Entrada sandstone	80	Sandstone, reddish-orange, massive.
	Carmel formation	40	Siltstone and claystone, red, interbedded.
Triassic	Wingate sandstone	350-475	Sandstone, orange, cross-bedded, massive.
	Chinle formation	1000±	Shale and siltstone, red, purple and gray.
	Shinarump formation		Sandstone, coarse-grained and conglomerate, light gray.
Permian	Cutler formation		
	DeChelly sandstone	200(?)	Sandstone, massive, cross-bedded, light brown to orange.

Igneous Rocks

Several igneous plugs can be seen within a radius of 25 miles. Shiprock, the most prominent, rises 1,700 feet above a surrounding plain (fig. 1). Several dikes strike north through the drilling area. These range from a few inches to several feet in width.

The plugs are basaltic, high in potash and ferro-magnesian minerals, and contain 50 percent or more xenolithic material. The dikes are also basic, but are more homogeneous than the plugs. Surrounding one of the plugs is a diatreme more than a thousand feet in diameter into which huge blocks of overlying sediments have collapsed. Beds of Mancos shale can be recognized at the stratigraphic level of the Summerville formation. Except in this one exposure, there is no evidence that the igneous activity has caused displacement of the sedimentary rocks.

The Chuska Mountain volcanics, a few miles to the south, intrude the Chuska sandstone. Nowhere in the area was it possible to establish a relationship between igneous activity and the emplacement of the ore.

GEOLOGY OF THE ORE DEPOSITS

Introduction

The ore deposits occur in the Salt Wash member of the Morrison formation on the east flank of the Carrizo Mountains. The ore minerals are carnotite and associated vanadium minerals. Pintadoite and pascoite are found as effluorescent scales, but are rarely in sufficient concentrations to constitute ore. Rossite, hewettite, and an unidentified black radioactive mineral were noted in some of the mine workings. Except for a few "rolls," the deposits are tabular. They either conform with the sandstone beds or cut bedding planes at low angles. The orebodies are commonly elongated, about three times as long as they are wide.

The East Carrizo deposits are concentrated, in several localities, within a particular sandstone unit, rather than through a vertical zone including many units. This circumstance favors stratigraphic ore controls rather than structural controls such as folds and joints. Only the lower half of the Salt Wash contains ore in the East Carrizo area; the upper half has been eroded from a large part of the area. The ore horizons occur from about 40 to 85 feet above the Bluff tongue. The ore is commonly found in association with carbon, limonite, gray mudstone, and gray sandstone. The thickness of the ore-bearing sand unit ranges from a few feet to several tens of feet.

On King Tutt Mesa, the ore lies along the margin of an old "channel"— a zone of permeability adjacent to flood plain beds. Ore near the Shadyside mine also lies in permeable thick channel sand, along the flank of an area of high mud content. This relation of ore to zones of permeability is further emphasized by the observation that all the deposits are elongated parallel to original sedimentation trends. In both sand units studied, carbon was apparently of prime importance as a precipitating agent. In the Oak Springs area, inter-relation of ore deposition and sedimentary features is not clear, but the frequency of carbon associations is suggestive.

The Salt Wash in the East Carrizo drilling area is about 220 feet thick and is predominantly sandstone with interbedded layers of mudstone. The sandstone is generally gray, the grain size is dominantly very fine to fine, and the grains are mostly quartz with a small proportion of black chert which gives a "salt and pepper" appearance to much of the rock. Cementing material is almost entirely calcium carbonate. The bedding changes laterally from one extreme of sharp festoon cross-bedding to the other extreme of platy, horizontal bedding. Most of the mudstone is red; some is gray. Actual clay-shale is seldom found.

The dominantly sandy Salt Wash, 220 feet thick in the East Carrizo area, changes facies southward very sharply and pinches out about 30 miles south of King Tutt Mesa 6/. Ten miles south of King Tutt, the Salt Wash section is about 100 feet thick and contains at least 50 percent mudstone. The mineralized portions of the Salt Wash in the East Carrizo area are near this marked facies change. There are barren Salt Wash exposures between King Tutt Mesa and Red Rock which lie even closer to the rather abrupt change from "high sand" to "high mud." One rim in the vicinity of the change from "high sand" to "high mud" content was stripped by a bulldozer, but no mineralization was found. Thus, in a stratigraphic trap region, where ore should be found if its deposition were dependent on stratigraphic control alone, there is no mineralization. From this, it would appear that the concentration of ore may not be dependent on a facies change alone. If ore solutions pass through an area, there must be some precipitating agent present, or there can be no mineralization.

A zone of interbedded sandstone and mudstone in the lower 20 feet of the Salt Wash is widespread throughout much of the East Carrizo area. This lower zone has been recognized at other places in the Carrizo and Lukachukai region. It is suggested that these initial heterogeneous Salt Wash deposits resulted from a gradual climatic change which allowed the encroachment of flood plain sediments into an area previously dominated by wind-blown sands of the Bluff tongue of the Cow Springs formation. The advancing "front" of the flood plain was followed, and overlain, by a system of braided, aggrading Salt Wash rivers which flowed in a southeasterly direction across wide, sandy straths a few hundred to a few thousand feet wide 7/. The individual streams probably varied considerably in width because in a braided system (e.g., stretches of the Platte and Arkansas) the river may split into two, six, or fifty braids over very short distances.

Structure contours drawn on the base of sandstone units indicate that relief on the flood plain, within a 1,000-foot square, was generally less than 20 feet. It is judged from the scarcity of plant remains that the climate was semiarid and, consequently, that the streams flowed intermittently. Carbon trash is common, however, in the sandstone at some localities. Logs are not common, but at one place in the King Tutt mine there is an accumulation of several logs in random orientation. The largest log is more than 30 feet long and at least one and one-half feet in diameter.

Because of the concentration of ore in specific sandstone units, certain characteristics of those units were mapped in an effort to predict the favorability of undrilled areas.

Sandstone thickness and mudstone to sandstone ratio maps outline the paths of permeability believed to have been followed by ore solutions and ground water. Sandstone and mudstone color maps also indicate the more permeable paths and may, in part, show zones of alteration by ore-bearing solutions. Carbon is an important indicator and is believed to be a control of mineral deposition. Limonite may indicate the presence of submegascopic carbon. ?

Isoradioactivity maps, with contours drawn on intensity of radioactivity, show the configuration of a "radiometric surface" and are thus a guide to ore deposits. Proper correlation of the sandstone units with anomalous radioactivity is, of course, essential. Accurate correlation requires correct evaluation of such variables as core-logging technique, lateral extent and homogeneity of the units, and the spacing of drill holes.

The authors and associates devoted most of their efforts to mapping and interpreting sedimentary trends and facies in order to determine probable ground water courses at the time of ore deposition. The following discussions are concerned primarily with sedimentation and such ore indicators as sandstone color and presence of carbon and limonite.

King Tutt Mesa

On King Tutt Mesa, two sandstone units, the King Tutt and the Shadyside, contain ore. The King Tutt sand was mapped over the entire mesa and is described below. The Shadyside sand was mapped only in the northwest quarter of the mesa.

King Tutt Sandstone

Description: The King Tutt sandstone unit is an interval of sandstone and interbedded mudstone within the Salt Wash member of the Morrison formation. This unit has been mapped only on King Tutt Mesa where it is about 50 feet thick and occupies the interval from about 20 to 70 feet above the Bluff sandstone. The King Tutt sandstone is dominantly very fine to fine grained, fairly well sorted, quartzose, generally gray but containing appreciable amounts of red sand, locally cross-bedded and generally friable. The mudstones which locally make up a large part of the unit are commonly red, but in places are gray or green.

Uranium-vanadium orebodies occur in the upper half of King Tutt sandstone, about 50 feet above the Bluff sandstone. The deposits are in a line 1,700 feet long across the south end of the mesa (fig. 5). Only one mineralized hole was found outside of this belt. Within this 1,700-foot line, individual orebodies have a maximum length of about 300 feet and a maximum width of about 100 feet.

Correlation: A fairly persistent unit of mudstone, bed "F" at the top of the King Tutt sand (fig. 6), can be correlated over most of the mesa. It averages about five feet in thickness. This unit is not as reliable a marker as the thicker and more consistent "Roof Mud" which occurs about 10 to 20 feet higher in the section. Hence, in practice, the correlation of "F" bed was largely determined by the position of the "Roof Mud."

The lower 20 feet of the Salt Wash on King Tutt Mesa is a sequence of interbedded lenses of sandstone and mudstone. No individual bed is continuous, but the zone as a whole persists over the mesa. An arbitrary datum plane 20 feet above the base of the Salt Wash was carried as the base of the King Tutt sand (fig. 6). It was observed from work at King Tutt that "parallel correlation" is a suitable method of correlating, given the following conditions: 1) that all evidence suggests little scouring, hence, little paleotopographic relief; 2) that the unit chosen is fairly thick so that correlation errors of a few feet are masked by the main body of the unit; 3) that correlation is not extended over too large an area, probably not more than a few thousand feet square.

Sedimentation and ore deposits: Two continuous belts of high sand ratio are shown as South Channel and Center Channel on figure 5. These sand zones are the deposits of streams over a period of many hundreds, perhaps thousands, of years. As such, they represent composite environments. It is believed that they served as channels for the movement of ore-bearing ground water. The term "channel" implies an original system of stream channels bounded laterally by flood plains, but in terms of permeability is equivalent to aquifer.

Because the Salt Wash streams were aggrading, it is probable that Center Channel is not a tributary to South Channel, but is a distributary which "braids" into South Channel in the southern part of the mesa. The boundaries of South Channel are drawn with a heavy line on the .20 contour of mudstone/sandstone, that is, where mudstone constitutes about 15 percent of the section. The thickest mud section was disclosed at hole 51, where the ratio of mudstone to sandstone is 1.71. Figure 7 is a photograph of the outcrop of the central part of the channel, taken at point "A" on figure 5.

Figure 6 is a cross section of South Channel from hole 51 to hole 154. The intertonguing mudstones and sandstones show lateral shifting of streams in the meander belt. The high mud area in the middle of South Channel (fig. 5) is shown, in holes 406 and 407, to be mud deposition in the lower half of the King Tutt unit.

Because all the ore is in the upper half of the King Tutt unit, the depositional environment of this portion is most important. During upper King Tutt time, the strath, or valley, had a maximum width of 1,200 feet and there was no mud bar in it. At its narrowest point, the strath was 400 feet wide. The map contours (fig. 5) suggest, and cross-bedding trends confirm, that the South Channel streams flowed southeast along the present southwest rim of the mesa, turned east across the south end of the mesa, and continued northeast along the southeast rim. The radius of curvature of the strath was slightly more than 2,000 feet. All the ore deposits are along the south flank of the channel and each is elongated parallel to the channel trend, which is also the permeability trend.

Center Channel is continuous across the mesa for several thousand feet. However, the mudstone to sandstone ratio is less than 0.10 in only a few places in the channel, and only one hole showed a ratio of less than 0.05. Center Channel is only a fraction of the width of South Channel and is, therefore, considered an inferior channel for ground water flow. Other areas of high sand ratio shown on the map are irregular lenses of sand which probably were not open to ground water flow.

Ore Indicators: Ore in the East Carrizo area is associated with gray mudstone, gray sandstone, carbon, and limonite. Figure 8 shows the distribution of these various indicators. Mineralization in the East Carrizo area was not sufficiently intense to alter the several feet of red mudstone to gray, as it did in the Uravan Mineral Belt 10/. If the mudstone bed is more than 1 foot thick, only the top and bottom few inches are altered. However, very thin partings of mudstone up to about 6 inches thick are quite sensitive to change.

Shaded portions of figure 8 indicate areas in which more than 75 percent of the mudstone galls, seams, and splits within the King Tutt sand are red. The unshaded portions show areas in which about 50 percent of the mudstone is gray and 50 percent is red. More than 75 percent of the mudstone is gray in fourteen holes (exclusive of offsets) along the south flank of South Channel. The unshaded area of equal amounts of gray and red mudstone correlates reasonably well with the high sand areas on figure 5. This correlation suggests that alteration of red mudstone to gray takes place along ground water courses. Alteration may have been accomplished by ground water alone. Weeks 11/ states that only 1 percent of the ferric iron pigment need be leached from red clay to change the color to gray. Throughout the stratigraphic section, red mudstone below a thick sandstone commonly has the upper few inches bleached. Reaction with ore-bearing solutions probably intensifies the bleaching action.

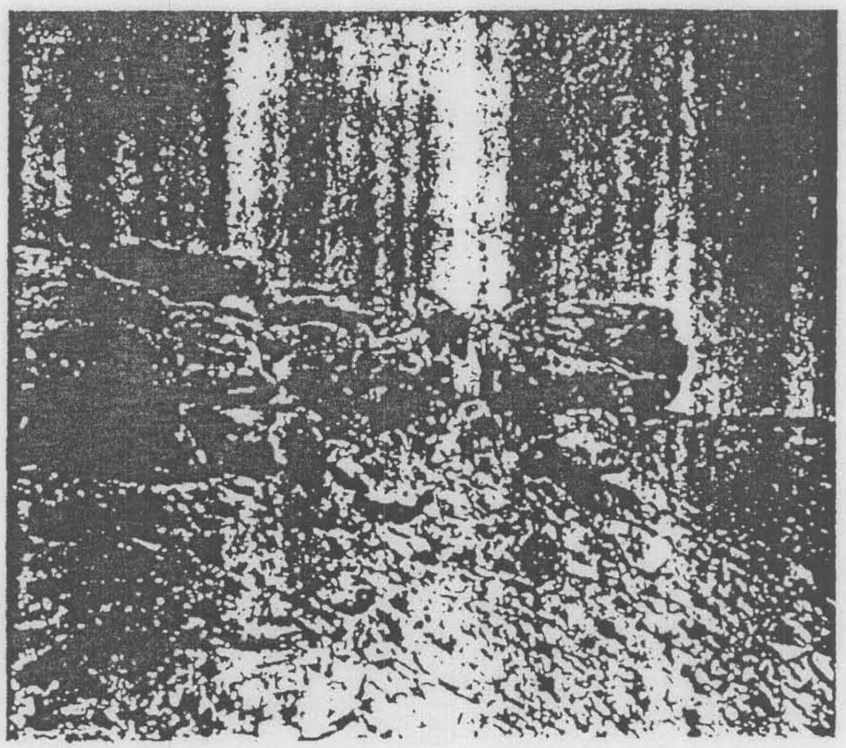


Figure 7. Outcrop of central part of channel, King Tutt Mesa, Arizona (Location shown on figure 5)

Logging at King Tutt Mesa was done by 14 geologists, and the color descriptions of sandstones are therefore subject to considerable variation. The area of high percentage of red color shown on figure 8 is only approximate and roughly indicates zones where red sand constitutes more than 50 percent of the King Tutt sand section. It is perhaps significant that the largest area of red sand is in the north part of South Channel. Previous work 12/ suggests that red sand represents a permeability barrier and that ore occurs in the vicinity of such barriers, other conditions being favorable. This would suggest that too much gray sand is unfavorable, as a lack of red sand may indicate a lack of trap conditions.

The importance of organic material in the precipitation of ore has been recognized for a long time. Results of the King Tutt drilling emphasize the significance of carbon association. The main concentration of organic material at King Tutt Mesa is along the outer edge of a curve in the meander belt of an ancient river.

Limonite is commonly associated with ore. Forty holes showed varying thicknesses of limonitic sand in the King Tutt unit. Twenty-three of the holes are located along the south flank of South Channel, where limonitic sand thicknesses range from 1 foot to 28 feet. An additional 17 holes containing limonitic sand are scattered around the mesa. Appreciable thicknesses of limonitic sand, up to 18 feet, were found in a few holes in the center of the mesa. Figure 8 shows that the areas of limonite concentration are also the areas of carbon concentration. This suggests that limonite is not necessarily an alteration product of iron sulfide which might have accompanied the ore solutions, but may be related genetically to carbon. The carbon may be organic material that escaped oxidation because it was deposited in a reducing environment. Sulfate-reducing bacteria, which liberate H_2S gas, are characteristic of that environment. The liberated sulfur combines with iron to form pyrite. Under these conditions, the presence of limonite may indicate carbon rather than ore.

Radioactivity: Isorad maps constructed from gamma-ray logs proved useful in the Shinarump 13/, and appear to be equally useful in the Salt Wash. Essentially, the isorad maps consist of contours drawn on radioactivity measured by the gamma ray probe.

Figure 9 is an isorad map of the King Tutt sand. It shows a belt of very high radioactivity across the south flank of South Channel. Radioactivity within the belt averages 5 to 10 times normal, and the three ore holes give especially high figures. The isorad contour trends correspond to the sedimentation trends shown by mudstone to sandstone ratios. Both isorad and facies contours on the south end of the mesa trend east, and contours over the rest of the mesa trend southeast. The zone of moderately high radioactivity, covering much of the central part of the mesa, lies in an area of high mud ratio.

Mudstone "kicks" are eliminated from the isorad figures because mudstones, although characterized by higher inherent radioactivity than sands, do not commonly carry ore. To include the mudstones in measurements of the sand section gives an erroneous picture of the amount of mineralization in the sand. However, a sand section that contains considerable mud beds also has considerable interstitial mud which is difficult to eliminate from gamma ray measurements. Consequently, the high radioactivity of the central part of the mesa should be interpreted as due partially to high mud content, and not as a clue to ore deposits.

The radioactive high in the north central part of the area was caused by a few inches of mineralization in hole 179. The hole was offset without favorable results. The high south of this was within the unfavorable area of dominantly red mudstone and red sandstone, and the extra radioactivity was interpreted as being due to mechanical failure or contamination of the hole wall by muddy drilling water. No offsets were drilled.

Conclusions: On King Tutt Mesa, the orebodies in the King Tutt sand lie along the south flank of South Channel, on the outer edge of a curve in an old meander belt. The deposits are elongated parallel to sedimentation trends. The width and high sand ratio of South Channel suggest that it was a better aquifer for ore solutions than Center Channel, which is barren of ore. The most obvious ore control in South Channel is the concentration of organic material along the south flank. The ore also lies in a belt of maximum permeability, bounded laterally by zones of high mud ratio and relatively impermeable red sand. These barriers may have concentrated the flow of ore-bearing ground water into the narrow belt of sand which contained organic material.

Within and adjacent to the area of mineralization in South Channel there is considerable alteration of mudstone from red to gray and an abnormal concentration of limonite, as well as carbon. The relative scarcity of these indicators in other high-sand areas of the mesa suggests strongly that there are no more economic deposits of ore present on the mesa in the King Tutt unit.

Isorad contours show a zone of abnormal radioactivity along South Channel where the orebodies are located. The King Tutt sand over the rest of the mesa shows no more than average gamma radiation, except at two holes. One of those holes was offset without results and the other hole was judged to be a poor risk for offsetting. Because the King Tutt sand isorad map points to the same areas of favorability as the lithologic maps, it appears that non-core drilling of similar lithologic sections would give adequate information for directing exploration.

Early Interpretations of Favorability - Research Phase of Drilling Project: King Tutt Mesa was drilled in successive stages on a grid pattern to determine the hole spacing which would give reliable subsurface information for predicting favorable ground. During phase 1, 17 holes were drilled 800 to 1,000 feet apart on a square grid, and the favorable areas of the King Tutt sand were interpreted by means of lithofacies maps (fig. 10) 8/.

During phase 2, 18 holes were added to bisect the spacing along north-south lines and another favorability map was constructed (fig. 11) 9/. Phase 3 drilling involved some close-spaced "paired" holes which were not suitable for determining favorability. For phase 4, the spacing was split along east lines, giving as a final result a square grid 400 to 500 feet on a side. A third favorability map was constructed (fig. 12). The final stage of the program, phase 5, involved the drilling of 42 holes spaced 200 feet apart in the favorable areas and an equal number in the unfavorable areas, in order to test the validity of the maps.

All orebodies in the King Tutt unit, as determined by close-spaced drilling, are superimposed on each favorability map. Phase 1 drilling (800- to 1,000-foot spacing) eliminated about one-third of the total mapped area as unfavorable. Subsequent drilling showed no ore in the unfavorable ground. Phase 2 drilling (partial 400- to 500-foot spacing) eliminated about one-half of the total mapped area as unfavorable. Subsequent drilling showed no ore in the unfavorable ground. Phase 4 drilling (400- to 500-foot spacing) eliminated about three-fourths of the total mapped area as unfavorable. Subsequent drilling still showed no ore in unfavorable ground. Every ore hole proved to be within the favorable rather than the semifavorable ground. One mineralized hole was found in the small patch of favorable ground in the center of the mesa, but no ore was located by offsetting. These maps show clearly that the main area of mineralization was recognized at the end of phase 2 and was closely delineated at the end of phase 4. The hole density at the completion of phase 2 was 3.2 holes per thousand square feet. The hole density at the end of phase 4 was 6.2 holes per thousand square feet. In terms of drill footage,

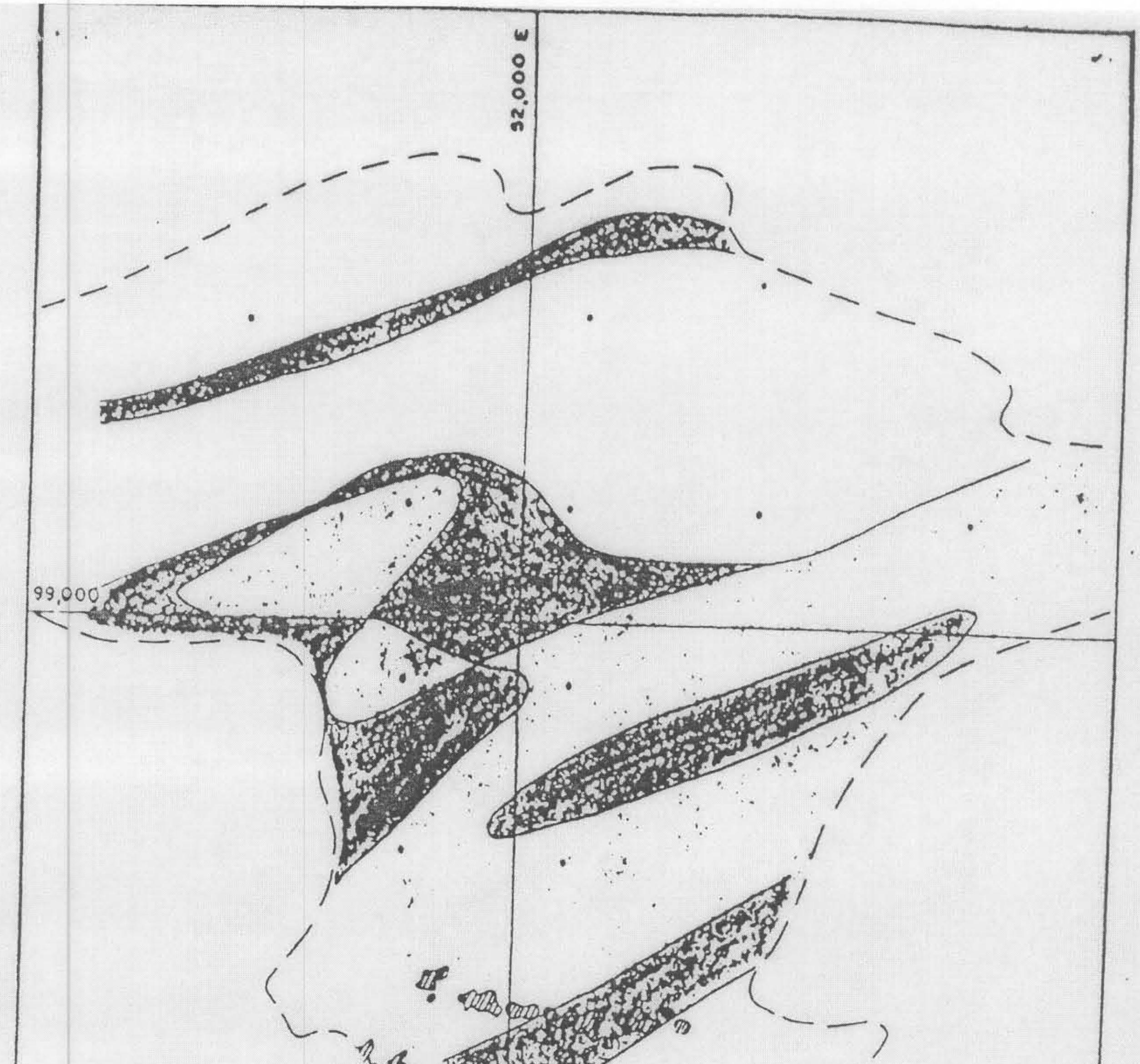


Figure 10. Favorable area — Phase I, King Tutt Mesa, Arizona

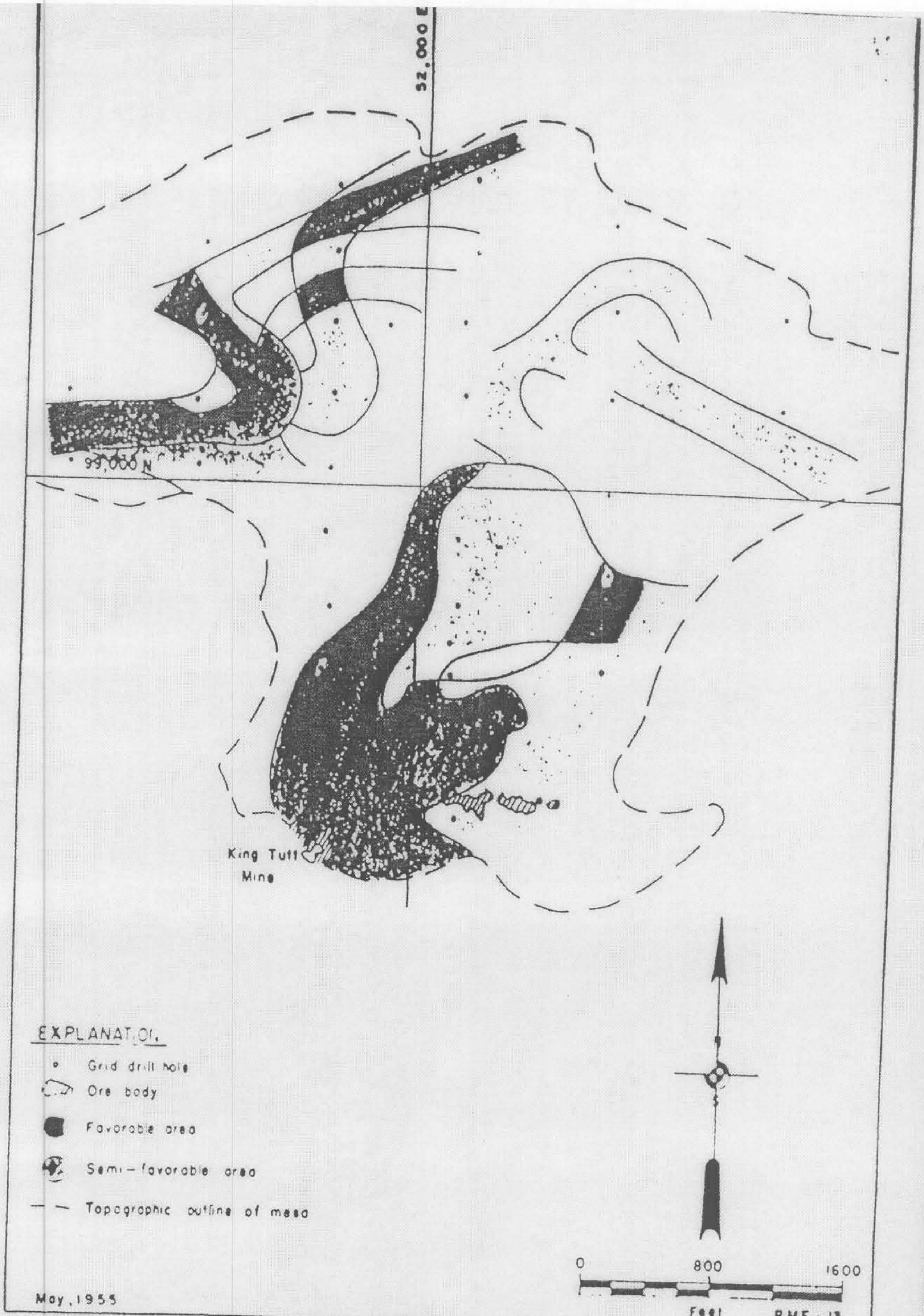


Figure 11. Favorable area — Phase 2, King Tutt Mesa, Arizona

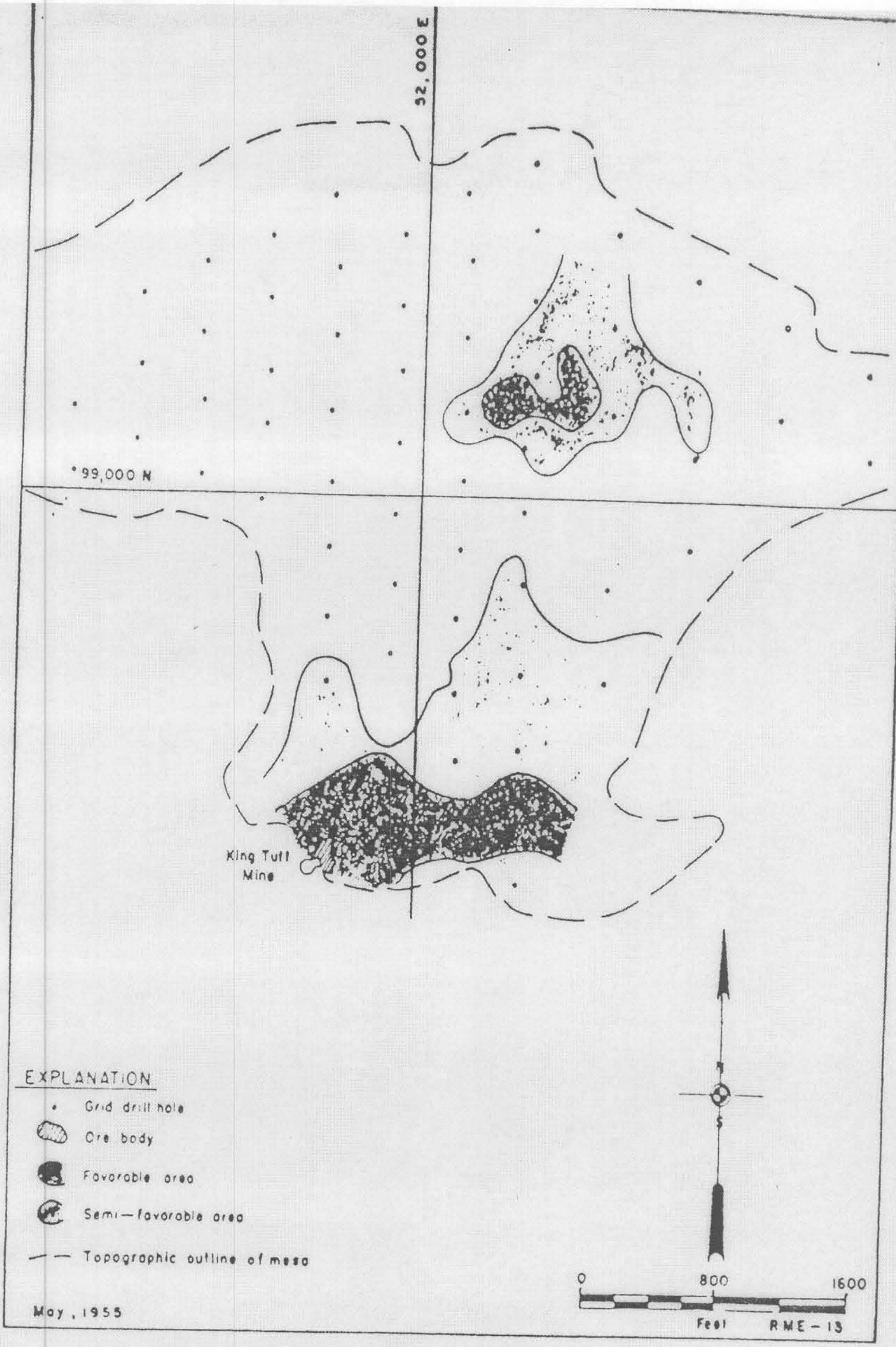


Figure 12. Favorable area—Phase 4, King Tutt Mesa, Arizona

the main area of mineralization was recognized by about 4,300 feet of drilling (phase 2). The mineralized area was closely outlined by a total of 8,300 feet of drilling (phase 4).

The delineation of orebodies in the South Channel, after the mineralized belt was clearly outlined, required an additional 21,000 feet of offset drilling. Two and one-half times as much footage was necessary to outline the ore as to locate it. Certain conclusions may be drawn from the above statements:

1. Geologic methods were successful in outlining favorable ground in the main sand unit.

2. Four hundred- to five hundred-foot hole spacing was necessary for accurate interpretation, although it is believed that preliminary surface geology (i.e., measuring sections and mapping sedimentation trends) would have eliminated some of the grid drilling.

3. The careful delineation of orebodies by offset drilling represents the main cost factor in exploratory drilling.

Shadyside Sandstone

Description: In the northwest quarter of King Tutt Mesa, there are several small orebodies in the Shadyside sandstone unit about 75 feet above the base of the Salt Wash. Within the drilling area (about 2,500 by 1,500 feet) shown on figures 13 and 14, the Shadyside sandstone ranges in thickness from 1 foot to more than 20 feet (cross section fig. 15). The sandstone changes vertically and laterally from fine-grained to silty, from well sorted to poorly sorted, from friable to limy and hard, and from gray to red. Tongues of red and gray mudstone and isolated lenses of mudstone are scattered through the sand. Two types of fresh water fossils were found in the Shadyside mine.

Correlation: The Shadyside sandstone is overlain by a continuous red mudstone, the lower few inches to several feet of which is commonly gray, fissile shale. This upper mudstone is the most persistent lithologic unit. The Shadyside sandstone is underlain by a discontinuous zone of red mudstone layers and lenses. Within certain restricted areas (perhaps 500 feet to 1,000 feet square) a single mudstone can be correlated as the base of the unit.

In order to construct a facies map over the whole area, it was necessary to select an arbitrary unit 15 feet in thickness measured downward from the base of the top mudstone. Correlation and mapping were not extended beyond the area shown on figures 13 and 14 because no mineralization was indicated by drilling to the south and east. Because of the inaccurate basal correlation, the Shadyside unit is difficult to segregate and map.

Sedimentation and Ore Deposits: Figures 13 and 14, mudstone-sandstone ratio maps of the Shadyside unit, show the pattern of deposition of the unit across the northwest quarter of the mesa. Braided and distributary streams flowed southeast and deposited well sorted channel sands between banks and bars of flood plain type material consisting of mudstone layers and poorly sorted, silty sand. The areas of mudstone-sandstone ratio higher than 50 are shaded. The areas of increasing ratio are areas of decreasing permeability and transmissibility. The large bank southwest of the Shadyside mine shows a maximum mudstone-sandstone ratio of 6.5, which is 6.5 feet of mud to 1 foot of sand. The central part of the bank is highly impermeable and, therefore, an unlikely place for the passage of ore solutions. Similar banks, with a lower mudstone-sandstone ratio, are seen on the map. In general, the ore deposits lie in the permeable channel sands adjacent to the relatively impermeable banks. The influence of permeability is shown also by the shape and orientation of the orebodies, each of which is elongated parallel to the sedimentation trend.

Ore Indicators: The association of organic material with ore is shown on the map. In and around each orebody there is an abnormal concentration of organic matter, generally in the form of carbon flakes or seams. Carbon is shown on the map only where it occurs within sandstone. Carbon flakes are commonly logged within gray mudstone, but this carbon was separated from the ore solutions by impermeable mud and shows no relation to the ore deposits.

Isorad maps of the thin Shadyside unit were of little value except at ore block No. 6. There the sand is relatively clean and thick. However, in most of the drilling area the Shadyside sand is too thin for proper isorad mapping. Figure 16 shows how the kick on a thin sandstone unit is "pulled out" by the overlying mudstones. Moreover, thin sandstones also tend to be more silty than thicker sandstones, hence the abnormally

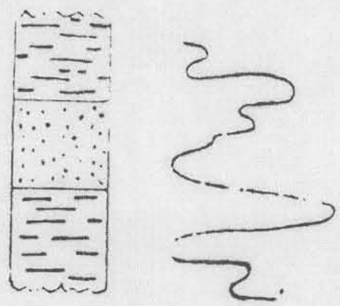


Fig. 16 - Shadyside sand, typical gamma impulse from sand influenced by mudstones

high radioactivity may be a result of excessive amounts of clay minerals. It is difficult, however, to know from the gamma log alone whether the greater radiation is due to additional silt or to additional uranium.

Shadyside Mine Area: This area includes the Shadyside mine and ore block No. 5 (fig. 13). The drilling area behind the mine was easily accessible. A total of 123 holes was diamond core drilled to an average depth of 123 feet. Total footage expended was 15,083 feet. The core was BX gauge, and core recovery averaged 95 percent. Most of the holes were gamma-ray logged.

Lithofacies maps drawn on close-spaced core holes are presented here to show details of sedimentation and ore deposition. Within the drilling area (roughly 600 x 500 feet) the Shadyside sandstone ranges in thickness from 1.5 to 14 feet. The unit is overlain and underlain by a continuous red mudstone. The basal few inches to several feet of the upper mudstone is commonly a gray, fissile shale. The top part of the lower mudstone in places splits away from the main mudstone unit and interfingers with sandstone. A few discontinuous mudstone splits occur within the sandstone. Figure 17 shows correlation within the drilling area of the Shadyside sandstone and the mudstone layers above and below.

An isolith map showing total feet of sandstone in the Shadyside unit (fig. 18) shows the pattern of deposition within the drilling area. The streams flowed southeast and deposited thick (up to 14 feet), well sorted, friable, predominantly fine-grained sand in the channels and thin (minimum thickness of 1.5 feet), silty, limy, predominantly very fine-grained sand and mudstone on the channel banks. The channel banks are shaded on the map. The main bank trends southeast to the middle of the area, where it splits and part of it turns south. The cross section E-F on figure 17 is drawn across the main bank and reveals the interfingering of mud and sand along the bank. A thick lens of sand in the southwest quarter of the map is bounded on the north and east, and apparently on the west, by thin muddy sand. The stream evidently entered from the west and curved south. The west unit of ore block No. 5 lies along the center and east flank of the channel immediately south of the curve and is elongated to the channel axis.

The east unit of ore block No. 5 shows elongation parallel to sedimentation, but is not as closely related to the pattern of sand thickness as is the west unit. In general, ore deposition and presumably permeability follow closely the pattern of sand thickness contours, but minor scour surfaces and irregular mudstone seams within the sandstone

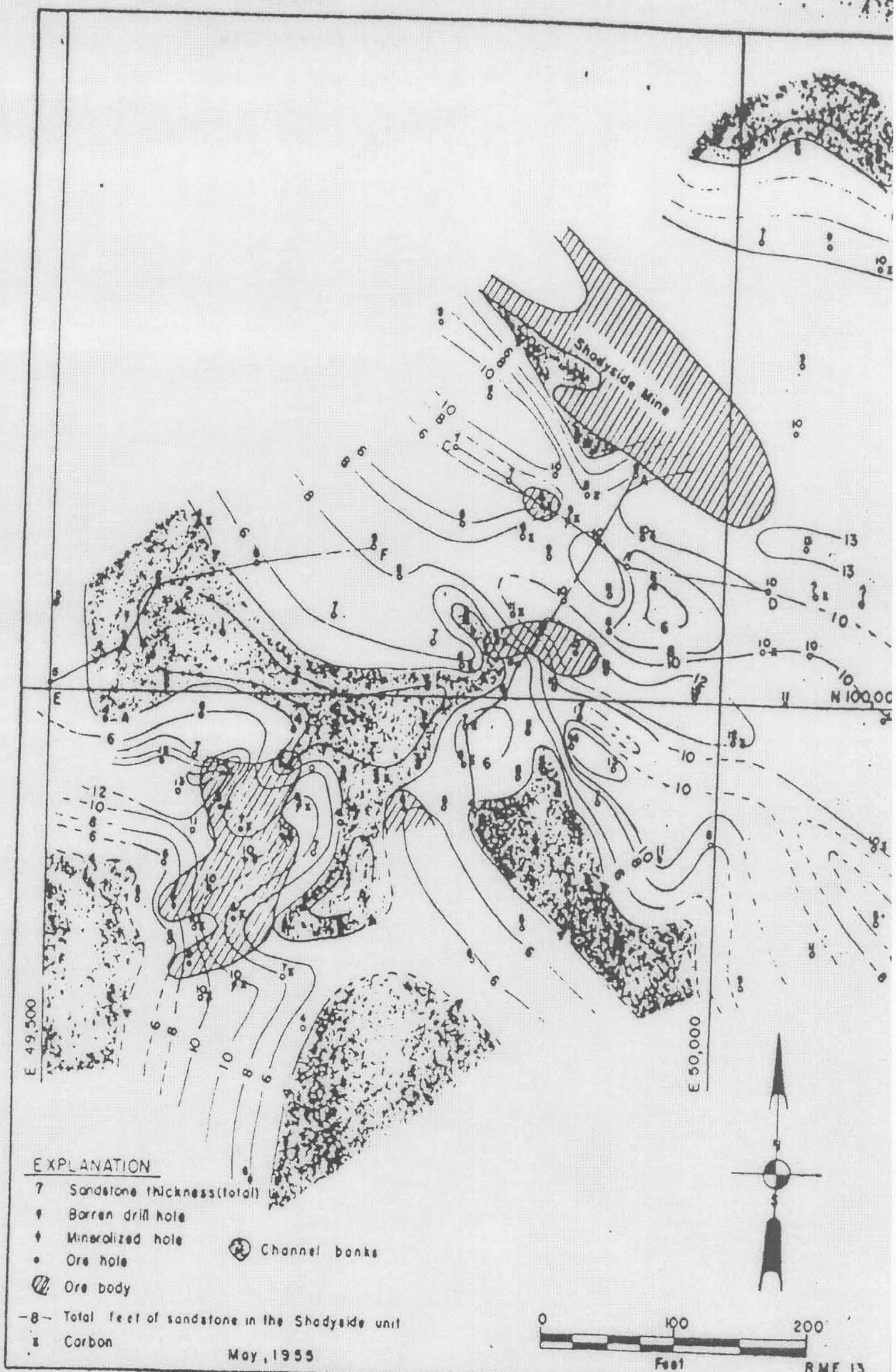


Figure 18. Sandstone isolith map of Shadyside unit, Shadyside mine area, Arizona—New Mexico

unit may have partially deflected the flow of solutions from this pattern. Other permeability factors, such as minor variations in sorting, cannot be predicted accurately with a sand thickness map. The outline of the Shadyside mine shows that it trends parallel to sedimentation and is bounded on the south and on the northeast by thin sand.

A map of the percentage of red sand in the Shadyside unit shows significant lateral changes in sandstone color (fig. 19). Every section logged as dominantly red sand also contained dominantly red mudstone galls, seams, and splits. This sandstone was most commonly recorded as very fine grained and silty. The sections of dominantly gray or tan sandstone contained dominantly gray mudstone galls, seams, and splits. This latter sandstone was recorded as very fine or fine grained and in only a few places as silty.

It is concluded by the authors that the red mudstone has been altered to gray by the passage of ore-bearing solutions, or by ground water. It seems probable that solutions did not pass through the red sand areas because of the increased siltiness and consequent lack of permeability associated with this color. Comparison of the red sand color map with the sandstone isolith map reveals that the red, silty areas correspond to the channel banks, and the gray or tan, larger grained and better sorted sand areas correspond to the channels.

The distribution of carbon is shown on figures 18 and 19. Forty-one of the 172 holes contain from a few inches to several feet of scattered carbon flakes and seams of carbon flakes. Only three of the carbon-rich holes contain appreciable amounts of red sand. Since the areas of high percentage of red sand are assumed to correspond to the old channel banks and to represent zones of low permeability, it appears that organic material is most commonly deposited and preserved in the channels. The largest concentration of carbon (near the west unit of ore block No. 5) is on the outside of a sharp curve in the southwesternmost channel. This carbon appears to have precipitated the ore of the west unit of ore block No. 5. The east unit is also associated with carbon, and the single ore hole in the middle unit contains carbon. There are, however, many more holes containing carbon which do not have mineralization.

Figure 20 is an isorad map which shows several radioactivity anomalies. The west and east units of ore block No. 5 are shown accurately as to position and trend. However, high radioactivity is apparent also in several other areas which do not contain significant mineralization.

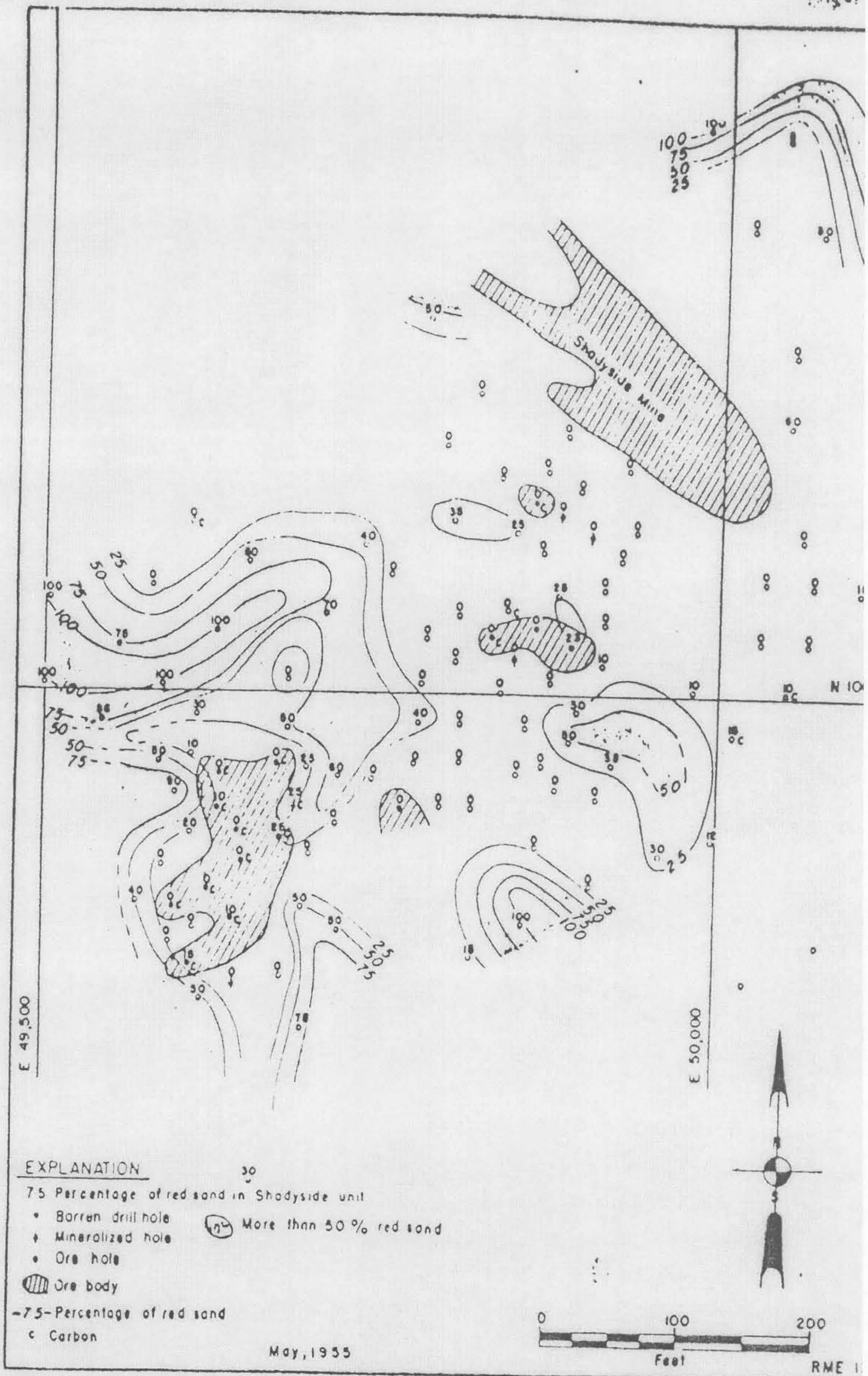


Figure 19. Percentage of red sand in the Shadyside unit, Shadyside mine area, Arizona—New Mexico

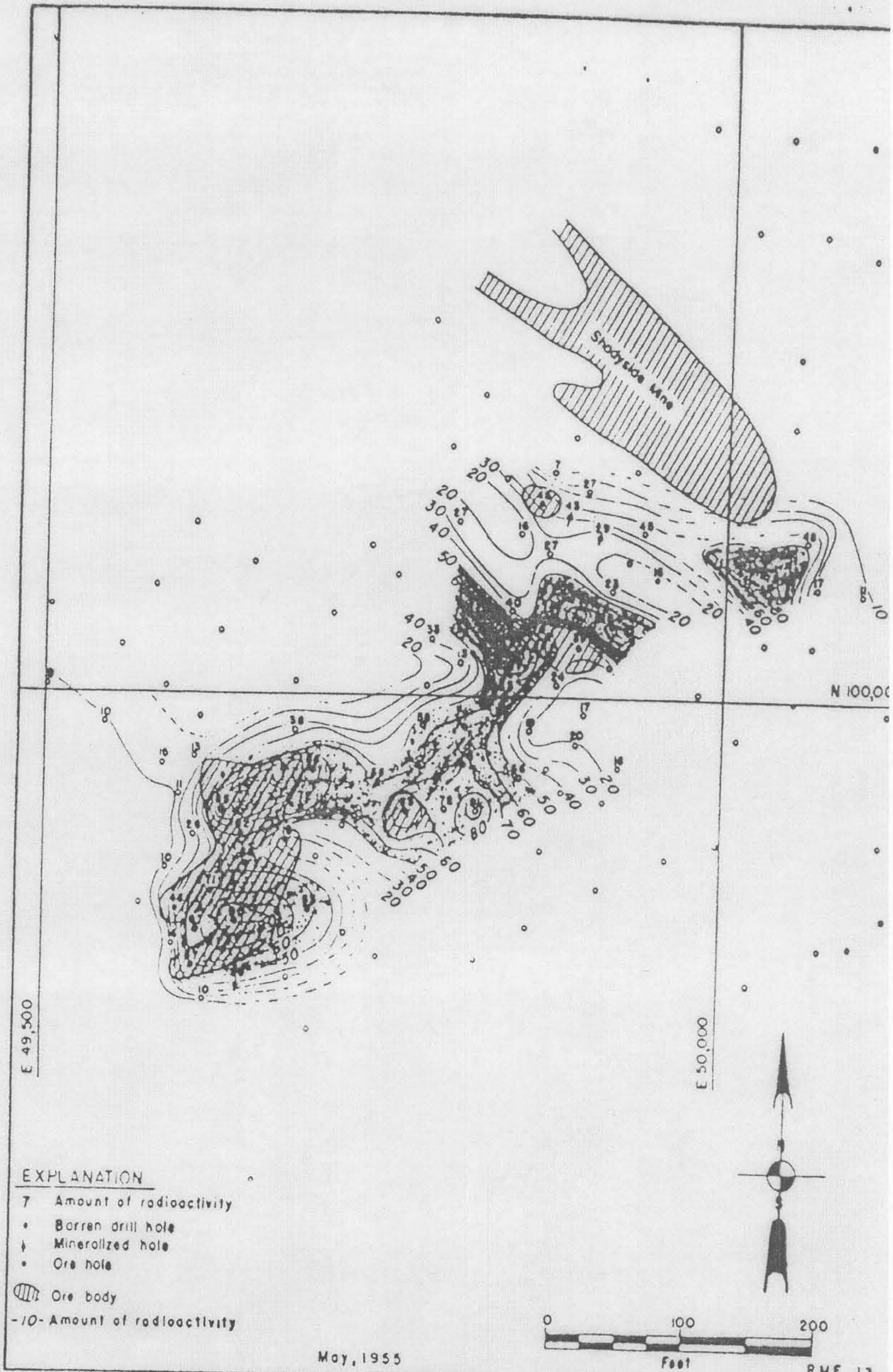


Figure 20. Isorad map of Shadyside sandstone

Arizona — New Mexico

It seems likely that the Shadyside sandstone unit is too thin and silty to give a gamma reading which will indicate consistently the relative amount of mineralization in the sand. As gamma logs were not made of all the holes, this conclusion is not based on adequate data. A tentative and alternate conclusion is that isorad maps are not effective for sandstone beds less than 10 feet thick which are overlain and underlain by thick mudstone beds.

Ore Blocks Nos. 7 and 8: Fifty-four holes were diamond core drilled to an average depth of 82 feet (fig. 14). Total footage expended was 4,474 feet. Core size was BX and core recovery averaged 94 percent. These orebodies are in sandstone which is 85 to 100 percent gray. Some of the barren holes showed 40 to 50 percent red sand. The ore is in thick, permeable sand adjacent to mud-rich zones and is associated with abundant carbon. Limonite did not occur in a sufficient number of holes to be of significance in determining favorable ground. There were insufficient data on which to base an isorad map.

Ore Block No. 6: Sixty-three holes were diamond core drilled to an average depth of 82 feet (fig. 14). Total footage expended was 5,091. Core size was BX, and core recovery averaged 85 percent. These orebodies are localized in sandstone which is over 90 percent gray. The ore is associated with abundant carbon and limonite. As the sand unit was relatively thick here, an isorad map was useful in determining the ore trend.

Summary

1. Deposition: The Shadyside sandstone was deposited across the northwest quarter of King Tutt Mesa presumably by braided distributaries flowing southeast. The resulting deposits, consisting of well sorted channel sands, are bounded by muddy, poorly sorted, flood plain type deposits.

2. Ore controls: The ore deposits occur in permeable channel sands adjacent to the channel banks. The channel sands are gray or tan and mineralized, whereas the bank sands are red and barren. The deposits were localized by accumulations of carbon in the channels and are elongated parallel to the sedimentation or permeability trend.

Oak Springs Area

Introduction

In the Oak Springs area (fig. 2) several discontinuous lithologic units were recognized. Separate correlative units were used in mapping different parts of the area. In the north part, the "C" unit was mapped, and in the central part, the "P" and "J" units. In the south part, correlation on lithology was extremely difficult, and in lieu of a better method, the geologist relied on arbitrary parallel line correlations. Subsurface data were subject to so many interpretations in the south area that no clear picture emerged from the studies.

The initial holes were spaced as near 1,000 feet apart as the rough topography would allow. Although a few holes were drilled as deep as 385 feet, most of the holes ranged in depth from 150 to 250 feet. As on King Tutt Mesa, the ore was confined to a zone from 45 to 85 feet above the Bluff sandstone.

"C" Unit

Description: The "C" unit occupies nearly the same stratigraphic interval as the King Tutt sand to the south. The unit has far less mudstone than the King Tutt sand, and the color of the sandstone is almost entirely gray. In grain size, sorting, bedding, and mineralogy, however, the two units are similar. Most of the mudstones are red and are less than 4 feet thick. The "C" unit can be correlated for 1½ miles in a northeast direction and for 4,000 feet at about right angles to that direction.

The Syracuse and Lone Star mines, the largest in the Oak Springs area, are located on the northwestern edge of the "C" unit (fig. 2). Close-spaced drilling in the proximity of these mines produced negligible results. The Canyon No. 1 and Canyon No. 2 mines are located along the southern edge of the "C" unit (fig. 21). Both mines are small, and the grade of ore has been lower than that of the two larger mines. An orebody was found behind the Canyon No. 1, but no ore was found in the vicinity of the No. 2 mine.

Correlation: On the basis of either one or two thin mudstone beds, the unit was divided into upper and lower parts. As the patterns of both parts coincide on the various maps, the unit could be treated either as one or two parts.

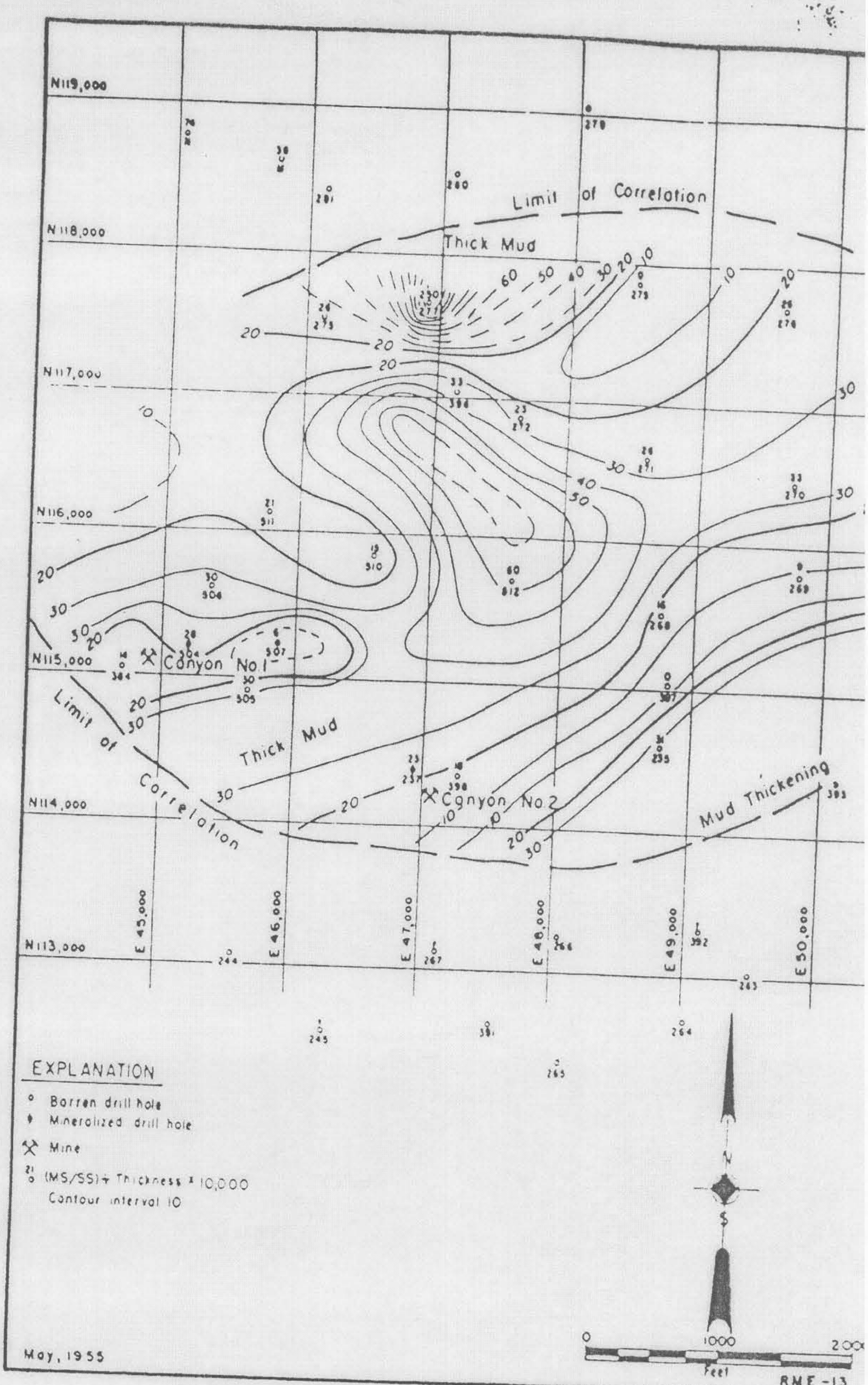


Figure 21 "C" unit, upper part, Oak Springs area
Arizona - New Mexico

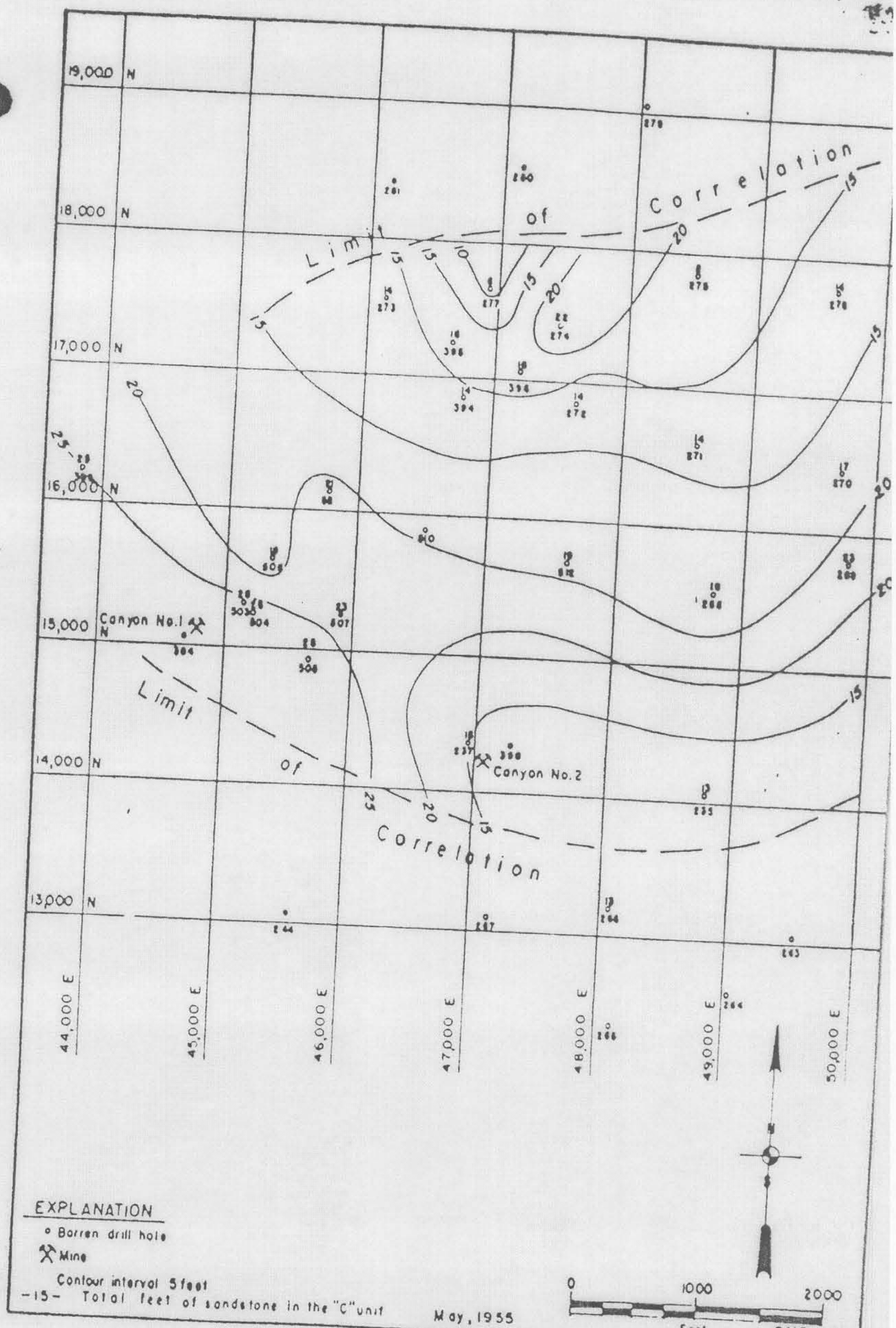


Figure 22. Sandstone isolith of "C" unit, upper part, Oak Springs area

Arizona — New Mexico

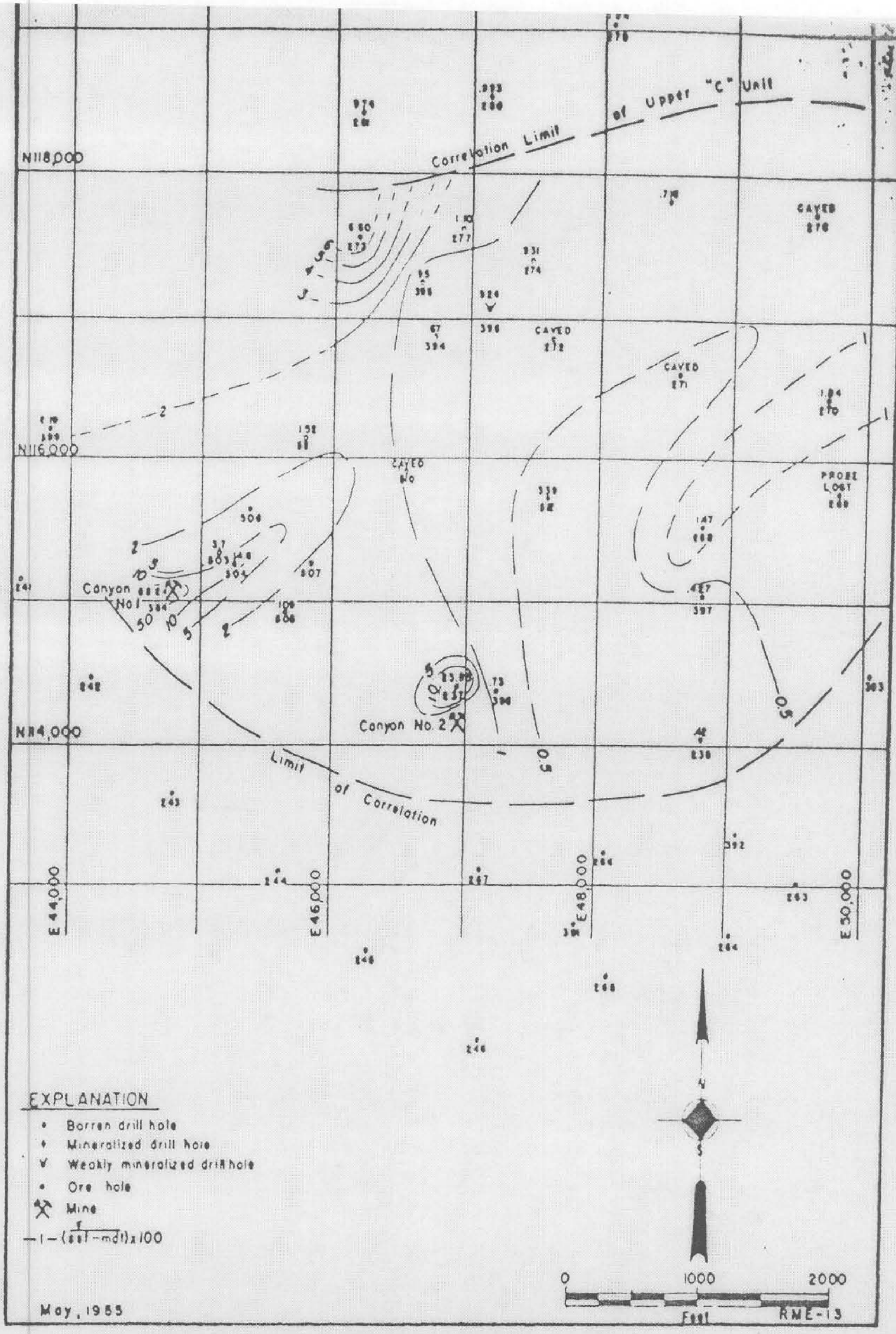


Figure 23. Isorad map of "C" unit, upper part, Oak Springs area Arizona—New Mexico

Sedimentation: Maps of primary sedimentary structures reveal a northeast stream direction. At the southeast edge, the "C" unit becomes thin and splits into several mudstones and sandstones, which intertongue with the units of the central area. Along the other edges, it is traceable as far as drill hole and rim information is available. The mudstone splitting the unit into upper and lower parts disappears to the north. A rapid increase in mudstone content around holes 273 and 277 appeared to offer favorable trap conditions (fig. 21). Test holes at that location encountered high radioactivity, but no ore (fig. 23).

The channel which contains both the Syracuse and Lone Star mines and the channel containing the Canyon No. 1 and No. 2 mines are both members of the "C" unit system, and are probably contemporaneous branches of a braided stream.

Though the work of Stokes indicates a general southeast trend of Salt Wash streams flowing in the Oak Springs area, his observations on the rim where the "C" unit is exposed support the subsurface evidence of a northeast trend for that unit. Stokes has suggested that variations in the courses of stream deposits offer the best opportunities for the accumulation of driftwood. As the latter, when carbonized, effects precipitation from later ore solutions, the same variations in stream courses offer the most favorable localities for ore deposition. The following fact appears to corroborate this observation: the one unit in the section which contains ore, the "C" unit, is the one whose trend diverges from the normal.

Ore Indicators: Carbon and limonite were found with the ore in every case. All the mines are located where there are accumulations of logs and vegetal debris. Color changes could not be used as guides because of the slight variation of color in the unit. In the immediate vicinity of an orebody, isorad maps gave discernible trends. Away from the ore, the radioactivity was uniformly low.

In compiling detailed maps of an orebody, a variation in the plotting of the isorad map proved more effective than the usual method. Normally in abstracting information from the gamma ray log, the area under the curve is computed for the whole unit. It was found that by limiting computations to the area under the peaks representing ore, a closer outline of the orebody is obtained. As in the standard procedure, the measured area is divided by the thickness of the section to get an average figure for radioactivity. A comparison of figures 24 and 25 shows that the contour lines for the second method agree more closely with the assay results.

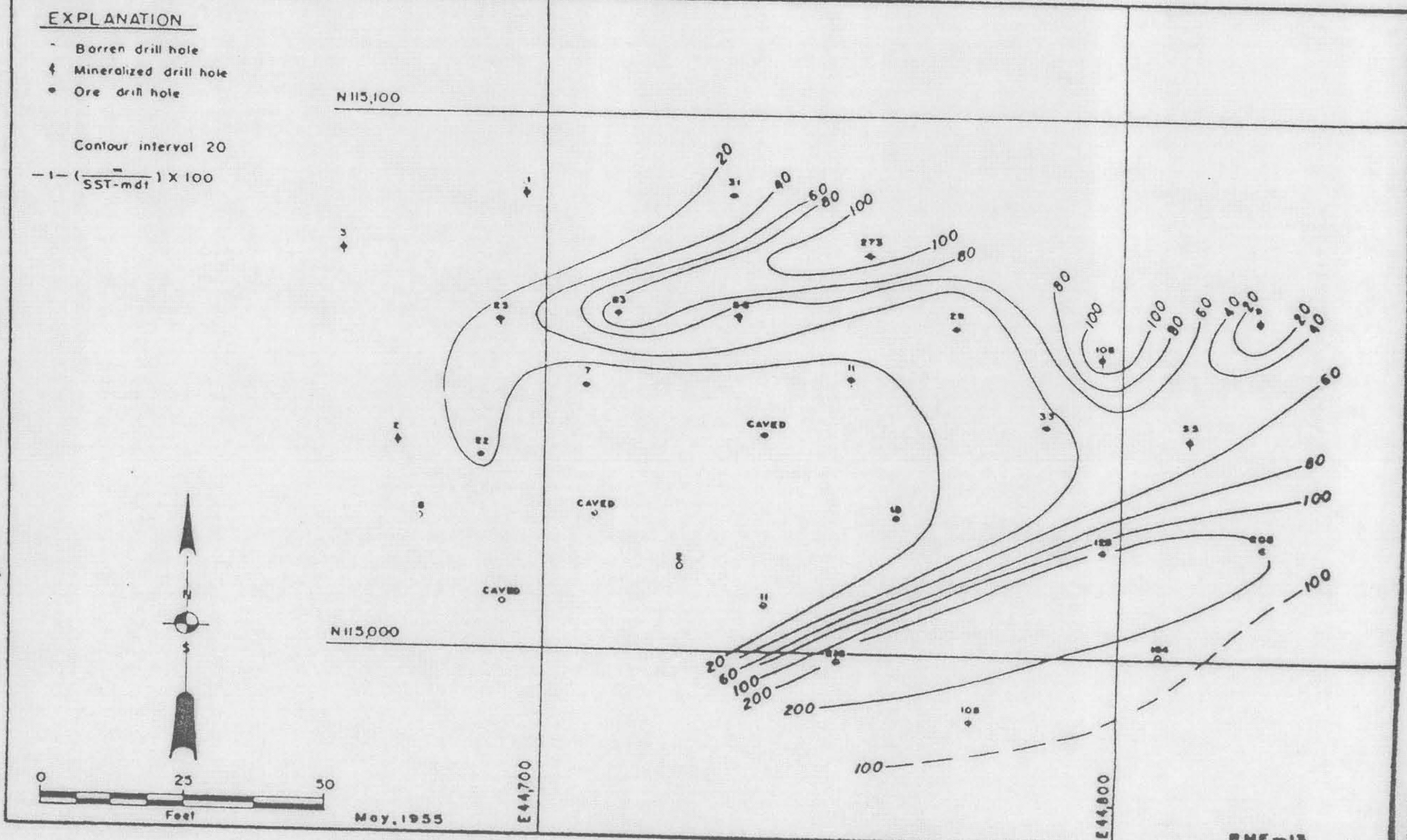


Figure 24. Isorad map "C" unit, Canyon No.1 mine, Oak Springs area

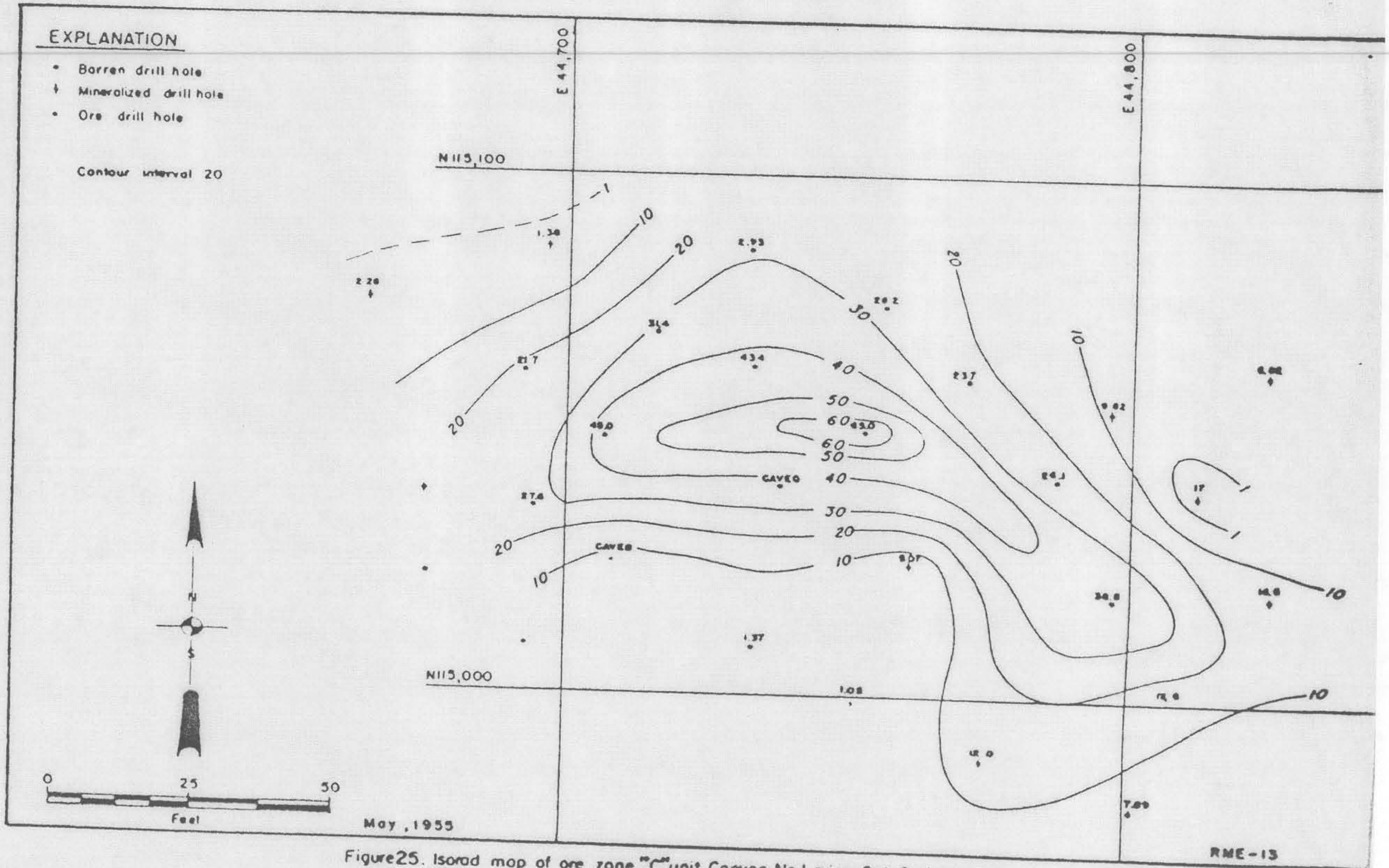


Figure 25. Isorad map of ore zone, "C" unit, Canyon No. 1 mine, Oak Springs area
Arizona — New Mexico

Conclusions: Studies of the "C" unit tend to confirm the conclusions reached in the studies of King Tutt Mesa. In units with high sandstone content, uniform gray color and low radioactivity, reliable guides to ore are rare, and mineralization is found only where there is abundant carbonaceous material. Consequently, subsurface studies are less fruitful in such areas.

"P" and "J" Units

The "P" and "J" units lie in the central part of the Oak Springs area. Generally both units contain evenly bedded mudstones, siltstones, and sandstones. Lateral changes in lithology are gradual on the northern and southern edges where they intertongue with other units. The units appear to consist of several interbedded lenses elongated in a northeast direction. Mineralization is very spotty and weak. No orebodies were developed in the area in which these units were mapped (fig. 26).

Other Units

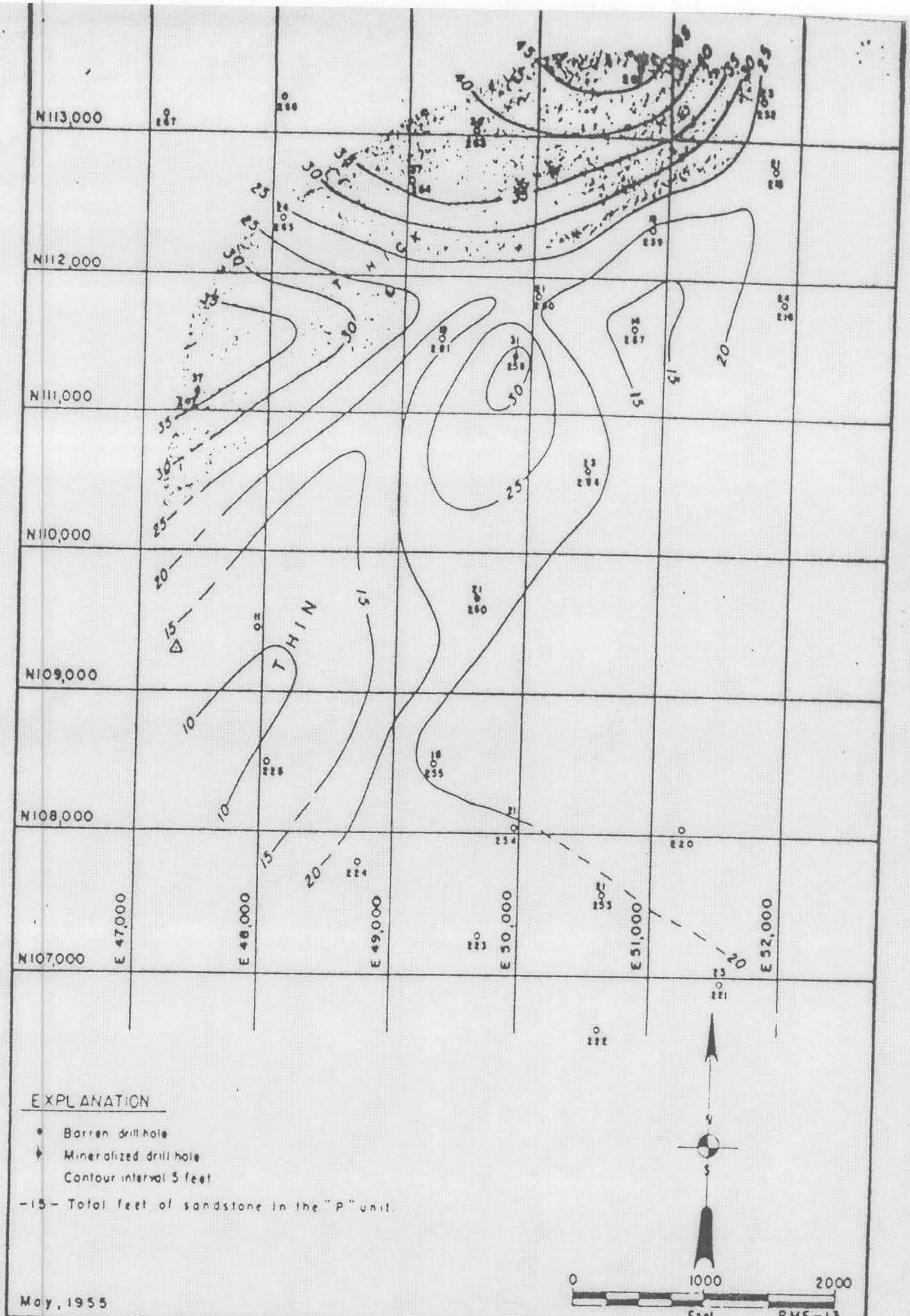
Along the southern margin of the Oak Springs area, many small sedimentary units merge. Though no interpretation was made of the subsurface data, lineation at the outcrop showed predominantly southeastward flowing streams. Several hundred tons of low-grade ore were mined from thin seams exposed at the surface, but drilling behind the outcrops failed to extend the orebodies.

The Oak Springs mine is located at the western margin of the drill area. The mineralized unit on which its operations are based cannot be traced along the outcrop, and topography prevents a connecting of the unit to other areas by drilling. The position of the Oak Springs mine above the Bluff sandstone (50 to 70 feet), and the easterly course of the mineralized unit, suggest that it may correspond with either the "C" or "P" units. Carbonaceous trash is abundant in the Oak Springs mine zone. The lithologic environment of the Oak Springs mine resembles that of the other mines.

SUMMARY AND CONCLUSIONS

Structure and Igneous Rocks

The beds in the drilling areas strike north and dip $1\frac{1}{2}^{\circ}$ to 3° east. Tertiary volcanics are intruded into the Salt Wash at several places. There is no obvious relation of either structure or igneous activity to the ore deposits.



Figrue 26. Sandstone isolith of the "P" unit, central area, Oak Springs
Arizona—New Mexico

Ore Deposits

The ore deposits in the drilling areas occur from 40 to 85 feet above the base of the Salt Wash. They range from small pods to deposits 100 feet wide by 300 feet long. Thickness and grade are relatively low.

Correlation

Generally, conventional correlation was based on recognizable lithologic units. In some places the top or bottom of a unit was so poorly defined that it was impossible to use a single horizon as the boundary. A method called "parallel correlation" was then used: arbitrary datum planes were projected at some arbitrarily selected height above the base of the formation, or above or below a marker bed. This method is workable because relief on the Salt Wash plain is very low and the sediments are spread evenly.

Parallel correlation should probably not be extended beyond a few thousand feet. For best results, the correlation unit should be fairly thick, probably over 25 feet, so that correlation errors of a few feet would be negligible.

Sedimentation and Its Relation to Ore Deposits

The Salt Wash sediments in this area were deposited by southeastward flowing braided aggrading rivers which dropped most of their mud load beyond the limits of the drilling area. Various types of subsurface lithofacies maps were used to outline the sedimentary environments within the drilled area. These maps were designed to show the permeable channels that controlled the movement of ground water. The majority of the ore deposits of this area lie in narrow channels or on the flank of wide channels. The wide "channels" of sand may best be termed straths or meander belts. The channel deposits are normally bounded on one or on both sides by a zone of decreasing permeability — these are the channel banks. Almost all of the deposits are elongated parallel to the sedimentation and permeability trends.

Ore Indicators

The "alteration colors" of gray or green mudstone are useful indicators of mineralization. In the vicinity of ore deposits these colors are dominant and may be shown by isopercentage maps of one color, total amount of one color, and relative abundance of gray mud versus red.

However, there are widespread sandstone beds in the Oak Springs area which are gray and barren. The same situation was recognized in some of the beds on the Lukachukai mesas where it was concluded that the complete absence of red sand areas meant the absence of trap conditions 14/. This interpretation is supported by the information from the East Carrizo drilling which shows a marked scarcity of dense, red "impermeable blocks" and also a scarcity of good orebodies. The frequency of both in the Lukachukai Mountains confirms this interpretation.

The role of carbon as a precipitating agent is clearly shown on the subsurface maps. In and around each orebody there is an abnormal accumulation of carbonaceous material, whereas, throughout the barren areas, carbon was found in only a few holes. Limonite occurs in abundance around the carbon, to which it is related. Gruner 5/ states that organic matter must be in a certain state of decomposition to cause precipitation of uranium, hence the carbon in barren holes may have been chemically incapable of precipitating ore. A second possibility is that ore solutions did not pass through those particular areas. A third possibility, indicated above, is that permeability barriers are necessary to retard movement of ore solutions in order that precipitation in a given area may reach ore grade.

Factors Influencing Ore Deposition

From the above discussion it is possible to isolate two factors which bear on the deposition of an orebody:

1. Variable permeability, which offers conduits for concentrated solution flow and forms barriers or dams which retard movement and allow sufficient time for precipitation to reach ore grade.

2. Precipitating agent: carbon.

These factors are interrelated in highly variable proportions. If the ore solutions are weak, optimum permeability and precipitating conditions cannot make a good orebody. In another case, carbon may be abundant, but there is insufficient permeability variation to cause concentrated flow, or the carbon may not be in the path of the main flow.

At many places in the East Carrizo area, it appears that carbon is the main control. This is true of most "high sand" areas where permeability is uniformly high. These areas almost never contain a large, good grade orebody.

Radioactivity

Isorad maps show the radioactivity of a sandstone bed and, thus, the increased radioactivity near orebodies. Hence, the maps provide an indirect method of locating ore. Unfortunately, isorad maps are not effective for a thin sandstone unit, one perhaps less than 10 feet in thickness, because of the effect of interstitial clay and the proximity of underlying and overlying mudstone beds. An isorad map of an orebody and the surrounding mineralized holes best shows the shape of the orebody, if contours are drawn on the actual ore-bearing zone within the sand unit.

Research Phase of Drilling

On King Tutt Mesa, the area of ore-grade mineralization in the King Tutt sand was closely delimited by a 400- to 500-foot grid pattern. Maps of the Shadyside sand were drawn at that spacing, but poor correlation of the thin lithologic unit made the results inconclusive. The addition of information from some of the close-spaced development drilling holes permitted the construction of facies maps for the northwest quarter of the mesa.

Development Drilling

Close-spaced offset drilling to delimit orebodies is the costliest element in Atomic Energy Commission exploration. Geologic information can be used to reduce the amount of offset drilling. The logs of holes drilled on King Tutt Mesa and logs from other projects should be studied more closely for clues to guide offset drilling. Mine-mapping should be undertaken in all districts to add information.

As shown on the King Tutt maps, orebodies tend to occur in groups and are elongated parallel to the sedimentation trend. Offset drilling should be planned to take full advantage of this fact. For example, offset spacing along the trend could be at a greater distance than offsets drilled normal to the trend.

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GEOLOGIC STUDIES AND DIAMOND DRILLING
IN THE EAST CARRIZO AREA, APACHE COUNTY,
ARIZONA, AND SAN JUAN COUNTY, NEW MEXICO
CONTRACT NO. AT(30-1)-1260

PART II

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GEOLOGIC STUDIES AND DIAMOND DRILLING
IN THE EAST CARRIZO AREA, APACHE COUNTY,
ARIZONA, AND SAN JUAN COUNTY, NEW MEXICO
CONTRACT NO. AT(30-1)-1260

PART II

PROJECT ENGINEERING

The drilling phase of the East Carrizo project was started on February 11, 1952. On that date, the Minerals Engineering Company placed four diamond drill rigs capable of taking 1 7/16 inches diameter core into operation. Contract strength was reached on February 12, 1952, when an additional two rigs were put into operation. On June 9, 1952, the drill complement was reduced to four rigs, and the project operated with these rigs until August 17, 1952, when maximum footage was reached.

Drilling at East Carrizo, from the point of view of costs and core recovery, was an extremely efficient operation. During the period February 11 to August 17, 748 drill shifts were worked in 146 days. The total footage bottomed was 100,038.0, and therefore 133.7 feet were drilled per drill per shift. An average of 6.5 holes were bottomed each working day.

Rapidity of drilling and resulting low direct AEC overhead charges, comparatively low contract cost, accessibility of the area along with the amenability of the topography to drill site construction, made for a situation that was ideal from an engineering and consequently a cost point of view.

Table 2 - Cost Analysis of East Carrizo Project - Contract AT(30-1)-1260

Total Contract Cost	$212,069.40
Salaries (AEC)	$ 14,251.49
Salaries (W-L)	$ 9,458.11
Travel (AEC)	$ 4,536.38
Travel (W-L)	$ 3,359.88
Equipment Usage	$ 7,739.27
Camp Supplies	$ 2,326.11
Sampling	$ 1,466.30
Total	$255,206.95
Cost per foot, AEC	$ 0.43
Cost per foot, contract	$ 2.12
Total cost per foot	$ 2.55
Cost per ton of ore developed	$ 16.29
Cost per pound of U_3O_8	$ 0.03

A study of ore reserves developed indicates that for the effort involved, the returns were not up to expectations. However, the fact that drilling time was short and therefore direct overhead costs low cut down the cost per ton of ore found to $16.29. The drilling contractor saved the Government approximately $2.60 per ton of ore found by drilling at a rate probably double that of other Commission diamond drill projects.

The East Carrizo project was broken down into two separate drill areas which exhibited different drill and engineering problems. The 2/3 of a square mile of King Tutt Mesa was an area of extremely close-spaced drilling. Some 698 holes were bottomed in this area. Move time was short and "mast up" moves were easily accomplished over the flat terrain. The water trucks that serviced the drills in this area had round trip runs of 3 miles. It was on King Tutt Mesa that 404.0 feet were drilled by one rig in a nine-hour shift. To accomplish this footage it was necessary to drill eight holes. Core recovery for these eight holes was average.

The Oak Springs area comprised eight square miles of drilling ground, with holes spaced as near to 1,000 feet apart as was commensurate with drill-site construction. Drill move time was of necessity long, and a round trip for the water haul was seven miles.

It was in the Oak Springs area that the only extraordinary condition for core drilling was encountered. The area involved has a surficial unconsolidated cover of diorite porphyry cobbles and pebbles that resisted attempts at casing by caving as soon as drilled. At the same time, movement of these cobbles and pebbles during the drilling process caused the wreckage of diamond drill bits and a consequent high bit cost. It was found that the water used during the drilling process helped the hole cave by washing out the finer fractions that tended to support the cobbles in place. The use of rotary bits along with air as the cooling and cutting removal medium proved successful in penetrating this overburden relatively economically. However, the setting of casing by using the weight of the casing string and the drill hoist proved impossible due to cave-ins, and it was concluded that in order to case these holes it would be necessary to feed the casing through the drill chuck using a hard-faced shoe to protect the casing threads and prevent damage to the lower end of the surface string. The feeding of casing through the chuck gave the drill operator the use of drill rotation and the crowding ability of the hydraulic cylinders, in addition to the gravity action of the weight of the casing string manipulated by the hoist. The Model Eight Chicago Pneumatic will not handle BX casing through the chuck jaws and as a result AX size casing was used. This AX casing was set with a minimum amount of trouble, and AX core was taken through this casing.

Table 3 - Drilling Statistics for Contract AT(30-1)-1260, East Carrizo Project, Apache County, Arizona

	King Tutt Mesa	Oak Springs	Total
Total drilled, feet	68,005.0	32,033.0	100,038.0
Total holes	698	250	948
Core recovery, percent	91.3	94.7	92.4
Average depth, feet	97.4	128	105.5
Offset holes			466
Mineralized holes			117
Average depth of mineralization			70
Ore holes			158
Ore blocks, developed			17
Ore per foot, tons			0.16
Average drills per shift			5.1
Feet per drill - shift			133.7
Working drill shifts			748
Personnel, AEC			5
Personnel, Service Contractor			4
Personnel, Drill Contractor			20

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE, EXPLORATION DIVISION
ORE RESERVE BRANCH
ORE RESERVE STATEMENTS, EAST CARRIZO I PROJECT, SAN JUAN COUNTY, NEW MEXICO, AND APACHE COUNTY, ARIZONA

Ore Reserve Calculations

A minimum thickness cut-off of 1.0 foot and a minimum grade cut-off of 0.10 percent U_3O_8 are used for Grade A ore except that thicknesses less than 1.0 foot are used provided the thickness-grade product is equivalent to 1.0 foot at 0.10 percent U_3O_8. Grade B ore, with grade cut-off of 0.05 percent U308 and 1.00 percent V_2O_5, is included with Grade A ore only in instances where Grade B material intervenes between Grade A intervals and the entire series is Grade A ore.

Various mineral horizons are correlated from drill hole data. The boundaries of lenses of Grade A ore are projected laterally up to 25 feet from the outer holes. Hole spacing up to 50 feet within orebodies is normally accepted for smaller orebodies and up to 90 feet for larger orebodies. Groups of lenses are combined into blocks constituting mining units by weighting the lenses and blocks by tonnage. In some instances, extremely high-grade assays for U_3O_8 in drill hole intervals are weighted by tonnage directly rather than by thickness with contiguous intervals of lower grade. A factor of 14 cu. ft. per ton is used. Ore-grade mineralization in a given lens penetrated by a single drill hole is classified as "inferred"; with more than one drill hole the classification is "indicated."

Ore Reserve Statements

A summary of Grade A reserves for the East Carrizo I drilling project is submitted. Ore reserve statements for each block of ore are also submitted. These statements consist of a cover sheet with descriptive information, a reserve summary sheet, a plan-section map of the ore block, and a tabulation of drill hole data.

The reserve summary sheet contains a detailed listing of the individual lenses in the various horizons.

Horizons of mineralization are denoted from the top downward by Roman numerals. Radiometric values for U_3O_8 are used for samples assaying less than 0.05 percent U_3O_8; these are shown on the maps as weakly mineralized. All other samples have chemical assays for U_3O_8. In some diamond drill holes, where core recovery in ore is nil, the thickness of the ore intercept and U_3O_8 content are estimated from gamma ray logs. Thickness is measured in tenths of feet.

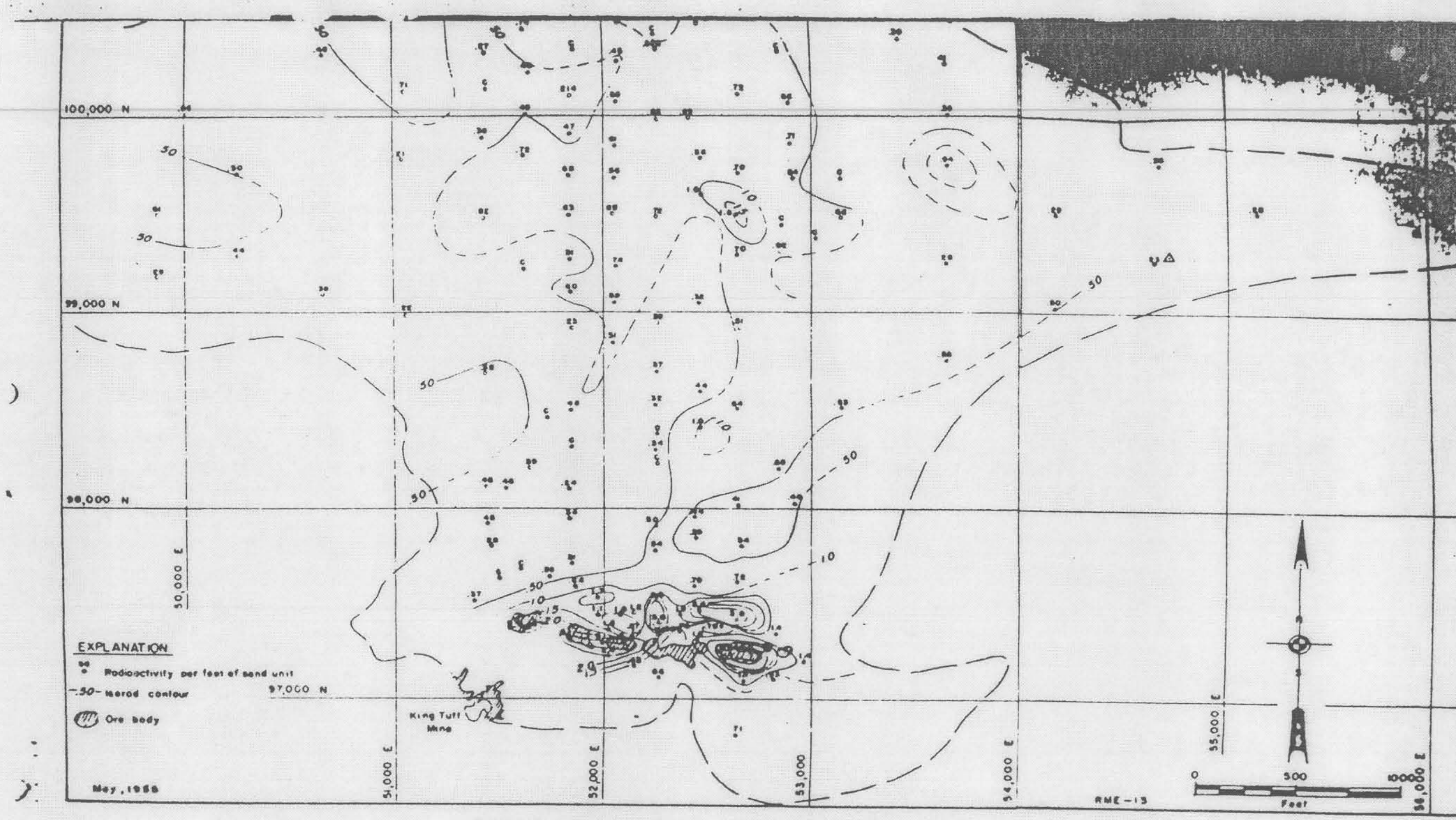

Figure 9. Isorad map of King Tutt sand, King Tutt Mesa, Arizona

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 1

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed, sec. 23, T. 29 N., R. 21 W., New Mexico, P.M.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to bottom of lowest ore horizon is 65 feet. Distance to drift to block 2 is 90 feet.

Metallurgy: Carnotite type ore, low vanadium, low lime. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Limits of orebody are determined by 12 ore holes, 10 mineralized holes and 18 barren holes. Further extension of the ore is unlikely.

Summary of Reserves: 0.46 ton ore and 1.9 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.7	0.22	0.70	1,250	5,500
Inferred Ore	1.0	0.17	0.17	110	374
Total	1.7	0.22	0.66	1,360	5,874

UNITED STATES ATOMIC ENERGY COMMISSION
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EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I — Ore Block No.: 2

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to bottom of lowest ore horizon is about 46 feet. Distance to block 3 is about 60 feet to the east. The block is in 2 lenses separated 60 feet horizontally. Most economical access is through blocks 3 and 4.

Metallurgy: Carnotite type ore usually low in lime but in some places may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Limits of orebody are determined by 24 ore holes, 14 mineralized holes and 16 barren holes. Significant extension of the ore limits is unlikely.

Summary of Reserves: 0.53 ton ore and 3.01 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.6	0.28	2.06	2,250	12,600
Inferred Ore	0.7	0.52	2.95	30	312
Total	1.5	0.28	2.07	2,280	12,912

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I   Ore Block No.: 3

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to bottom of lowest ore horizon is about 56 feet. Adit length from south rim is about 380 feet. The ore occurs in 3 horizons with a vertical separation of about 2 feet between the horizons.

Metallurgy: Carnotite type ore usually low in lime but in some places may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Limits of orebody are determined by 20 ore holes, 9 mineralized holes and 23 barren holes.

Summary of Reserves: 0.76 ton ore and 3.6 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.8	0.23	2.23	2,600	11,960
Inferred Ore	1.4	0.27	0.11	200	1,080
Total	1.8	0.23	2.07	2,800	13,040

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EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I — Ore Block No.: 4

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 24, T. 29 N., R. 21 W., New Mexico, B.L.&M.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to the bottom of the lowest ore horizon is about 58 feet. Adit length from the rim to the east at an elevation of 5,490 feet is about 380 feet. Distance to block 3 is about 50 feet.

Metallurgy: Carnotite type ore usually low in lime but may in places be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Limits of orebody are determined by 19 ore holes, 14 mineralized holes and 29 barren holes. Significant extension of the ore limits is improbable.

Summary of Reserves: 0.52 ton ore and 2.91 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.9	0.29	2.16	2,040	11,832
Inferred Ore	1.7	0.24	2.28	390	1,872
Total	1.9	0.28	2.18	2,430	13,704

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 5

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, B.L.&M.

Claim: Shadyside #2

Owner: Navajo Indian Council
Lessee: V.C.A.

Mining Availability: Adit length to ore from rim at elevation of 5,607 feet is about 385 feet. Access through Shadyside mine may be most economical. Depth to bottom of lowest ore is about 104 feet.

Metallurgy: Carnotite type ore usually low in lime but may in places run over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence 87 miles paved road to Durango Mill.

Discussion: Ore limits are determined by 22 ore holes, 16 mineralized holes and 85 barren holes. Significant extension of the ore limits is unlikely.

Summary of Reserves: 0.14 ton ore and 0.60 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.8	0.22	2.71	1,510	6,644
Inferred Ore	3.0	0.18	1.12	470	1,692
Total	2.1	0.21	2.33	1,980	8,336

UNITED STATES ATOMIC ENERGY COMMISSION
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EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I — Ore Block No.: 6

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim: Shadyside (?)

Owner: Navajo Indian Council
Lessee: V.C.A.

Mining Availability: Minimum depth to ore is about 50 feet. Drifting distance to rim is roughly 200 feet.

Metallurgy: Carnotite type ore usually low in lime but may in places run over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence 87 miles paved road to Durango Mill.

Discussion: Ore limits are determined by 21 ore holes, 4 mineralized holes and 38 barren holes. Significant extension of the ore limits is unlikely.

Summary of Reserves: 0.36 ton ore and 1.54 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.9	0.23	3.02	1,430	6,578
Inferred Ore	1.7	0.24	2.38	210	1,008
Total	1.9	0.23	2.94	1,640	7,586

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 15

Date: August, 1952

District: Shiprock
Area : Oak Springs
Locality: East Carrizo
Township: Unsurveyed sec. 15, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim:

Owner: Navajo Indian Council
Lessee:

Mining Availability: Depth to bottom of ore is about 79 feet. Distance from rim at elevation of 5,975 feet is about 500 feet. The ore occurs in 4 lenses separated in 2 horizons. Approximately 125 feet of barren drifting will be needed to connect the ore lenses.

Metallurgy: Carnotite ore usually low in lime but in places over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits are determined by 5 ore holes, and 9 barren holes. Extension of the ore limits is probable.

Summary of Reserves: 0.21 ton ore and 1.67 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	—	—	—	—	—
Inferred Ore	2.2	0.40	4.43	270	2,160
Total	2.2	0.40	4.43	270	2,160

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GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 16

Date: August, 1952

District: Shiprock
Area : Oak Springs
Locality: East Carrizo
Township: Unsurveyed sec. 2, T. 29 N., R. 21 W., New Mexico, B.L.&M.

Claim:
Owner: Navajo Indian Council
Lessee:

Mining Availability: Depth to base of the ore is about 193 feet. Distance from rim at an elevation of 5,665 feet is about 230 feet. Low grade, thickness, and small tonnage prevent economic exploitation under present conditions.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 1 ore hole and 3 barren holes. Some extension of the ore limits is possible.

Summary of Reserves: 0.05 ton ore and 0.16 lb. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	—	—	—	—	—
Inferred Ore	0.7	0.16	1.46	40	128
Total	0.7	0.16	1.46	40	128

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GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 17

Date: August, 1952

District: Shiprock
Area : Oak Springs
Locality: East Carrizo
Township: Unsurveyed sec. 10, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim: North Canyon

Owner: Navajo Indian Council
Lessee:

Mining Availability: Depth to base of ore is about 64 feet. Distance from the rim at an elevation of 5,830 feet is about 350 feet. Small tonnage, thinness and depth of the orebody prevent exploitation under prevailing conditions.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits are determined by 1 ore hole and 2 barren holes. Extension of the ore boundaries is probable.

Summary of Reserves: 0.08 ton ore and 0.39 lb. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	--	--	--	--	--
Inferred Ore	0.6	0.23	2.15	30	138
Total	0.6	0.23	2.15	30	138

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SUMMARY OF ORE RESERVES, EAST CARRIZO I PROJECT

Horizon Lens	INDICATED Thickness Ft.	INDICATED Percent U_3O_8	INDICATED Percent V_2O_5	INDICATED Tons Ore	INFERRED Thickness Ft.	INFERRED Percent U_3O_8	INFERRED Percent V_2O_5	INFERRED Tons Ore	TOTAL Thickness Ft.	TOTAL Percent U_3O_8	TOTAL Percent V_2O_5	TOTAL Tons Ore
1 I a	0.6	0.43	0.01	70	--	--	--	--	0.6	0.43	0.01	70
b	--	--	--	--	1.0	0.20	0.25	70	1.0	0.20	0.25	70
II a	0.7	0.34	1.82	200	--	--	--	--	0.7	0.34	1.82	200
b	--	--	--	--	1.0	0.12	0.02	40	1.0	0.12	0.02	40
III	2.0	0.18	0.52	980	--	--	--	--	2.0	0.18	0.52	980
Total Block 1	1.7	0.22	0.70	1250	1.0	0.17	0.17	110	1.7	0.22	0.66	1360
2 I	--	--	--	--	0.7	0.52	2.95	30	0.7	0.52	2.95	30
II a	1.6	0.25	1.95	1800	--	--	--	--	1.6	0.25	1.95	1800
b	1.4	0.39	2.48	450	--	--	--	--	1.4	0.39	2.48	450
Total Block 2	1.6	0.28	2.06	2250	0.7	0.52	2.95	30	1.5	0.28	2.07	2280
3 I	1.8	0.23	2.23	2600	--	--	--	--	1.8	0.23	2.23	2600
II a	--	--	--	--	1.5	0.30	0.11	75	1.5	0.30	0.11	75
b	--	--	--	--	1.6	0.35	0.13	80	1.6	0.35	0.13	80
c	--	--	--	--	1.0	0.10	0.07	50	1.0	0.10	0.07	50
Total Block 3	1.8	0.23	2.23	2600	1.4	0.27	0.11	200	1.8	0.23	2.07	2800
4 I a	1.6	0.21	1.16	120	--	--	--	--	1.6	0.21	1.16	120
b	--	--	--	--	1.0	0.15	0.02	20	1.0	0.15	0.02	20
II a	--	--	--	--	2.1	0.19	0.99	105	2.1	0.19	0.99	105
b	--	--	--	--	2.6	0.31	6.96	90	2.6	0.31	6.96	90
III	2.0	0.31	2.52	1500	--	--	--	--	2.0	0.31	2.52	1500
IV a	--	--	--	--	0.7	0.17	0.22	40	0.7	0.17	0.22	40
b	--	--	--	--	0.9	0.23	0.32	30	0.9	0.23	0.32	30
c	1.6	0.36	0.12	185	--	--	--	--	1.6	0.36	0.12	185
d	--	--	--	--	1.0	0.13	1.64	50	1.0	0.13	1.64	50
e	--	--	--	--	1.5	0.43	1.04	55	1.5	0.43	1.04	55
f	1.7	0.15	1.99	235	--	--	--	--	1.7	0.15	1.99	235
Total Block 4	1.9	0.29	2.16	2040	1.7	0.24	2.28	390	1.9	0.28	2.18	2430
5 I a	--	--	--	--	3.5	0.16	1.29	120	3.5	0.16	1.29	120
b	1.5	0.24	1.98	115	--	--	--	--	1.5	0.24	1.98	115
c	--	--	--	--	4.6	0.21	1.47	160	4.6	0.21	1.47	160
d	--	--	--	--	1.1	0.15	1.16	40	1.1	0.15	1.16	40
II a	2.2	0.15	1.64	440	--	--	--	--	2.2	0.15	1.64	440
b	--	--	--	--	1.7	0.16	0.05	60	1.7	0.16	0.05	60
c	--	--	--	--	0.9	0.12	0.20	45	0.9	0.12	0.20	45
d	1.7	0.25	3.28	960	--	--	--	--	1.7	0.25	3.28	960
e	--	--	--	--	1.3	0.22	1.77	45	1.3	0.22	1.77	45
Total Block 5	1.8	0.22	2.71	1510	3.0	0.18	1.12	470	2.1	0.21	2.33	1980
[illegible]	[illegible]	--	--	--	1.6	0.18	2.26	60	1.6	0.18	2.26	60
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.27	1.58	80

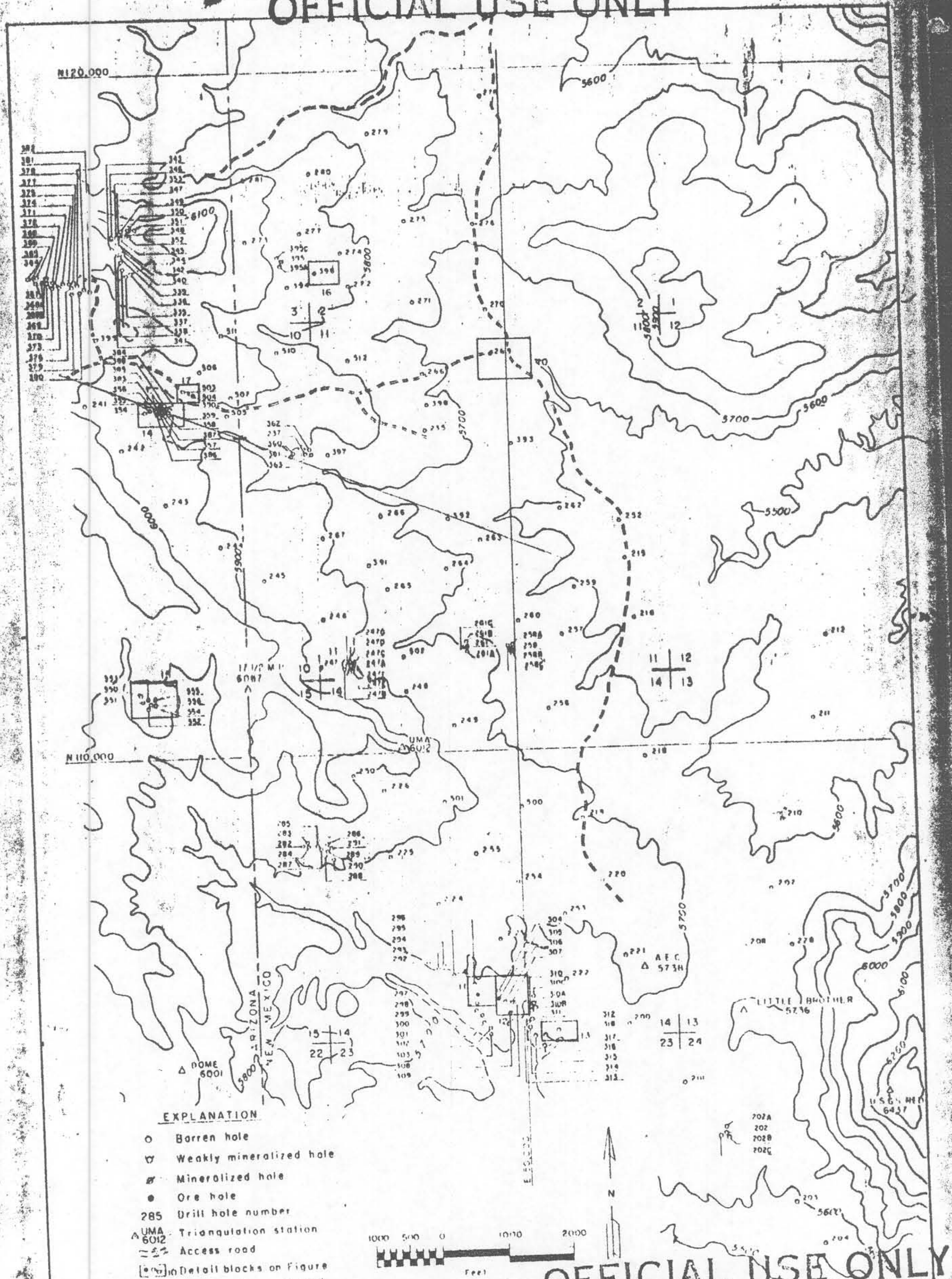

Figure 28. Primary Drill Hole Map, East Carrizo No. 1 Drilling Project Oak Springs Area, Apache County Arizona, and San Juan County New Mexico

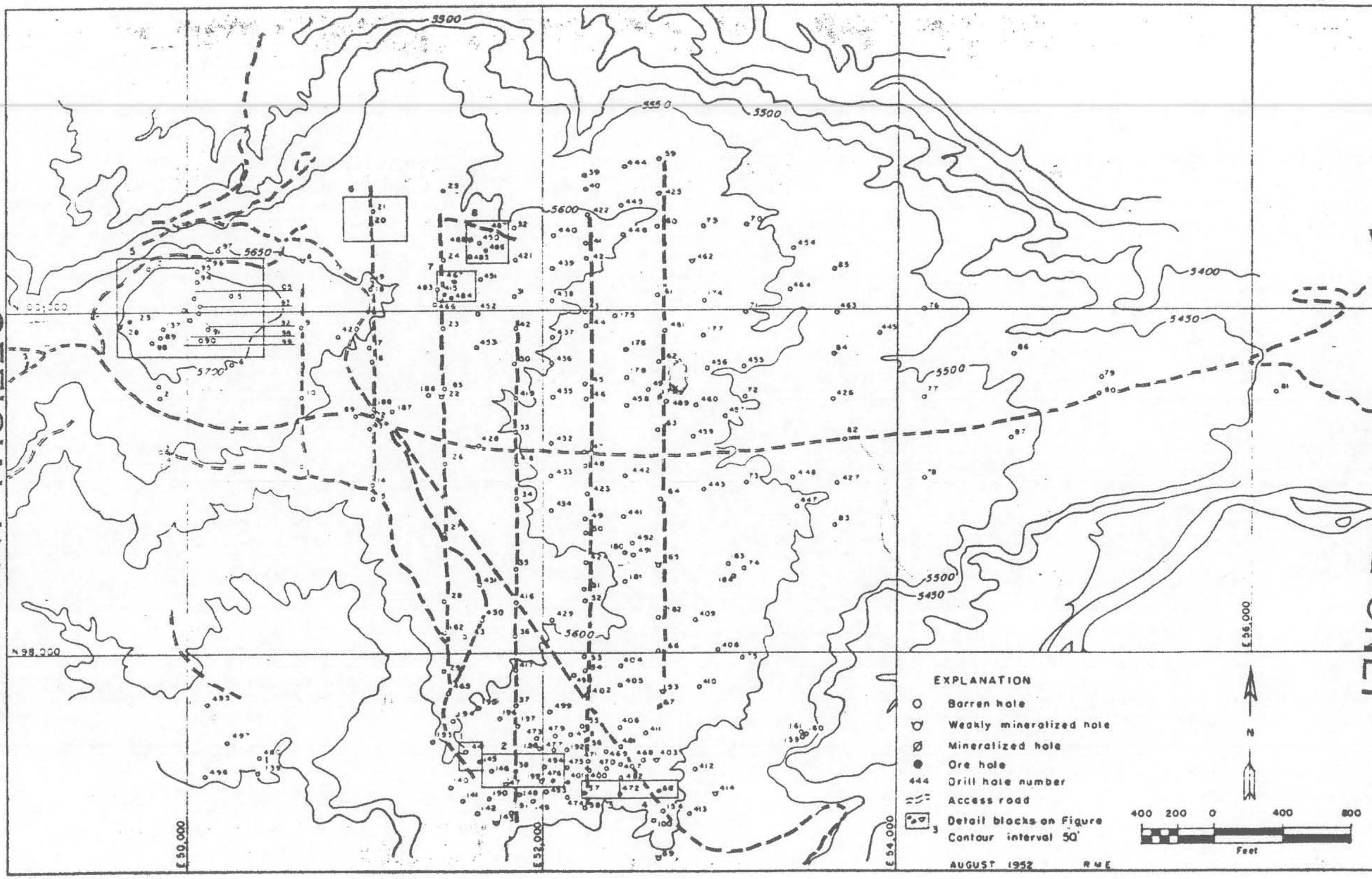

Figure 27. Primary Drill Hole Map, East Carrizo No.1 Drilling Project, King Tutt Mesa Area
Apache County Arizona, and San Juan County New Mexico

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UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I   Ore Block No.: 7

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, B.L.&M.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to base of ore is a minimum of about 62 feet. Adit length from rim to northeast of elevation of 5,960 feet is about 730 feet. Incline length from northeast is about 155 feet. The ore occurs in 3 lenses all in the same horizon.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 9 ore holes, 3 mineralized holes and 20 barren holes. Significant extension of the ore limits is unlikely.

Summary of Reserves: 0.46 ton ore and 3.36 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.5	0.36	3.13	910	6,552
Inferred Ore	1.5	0.40	4.77	130	1,040
Total	1.5	0.37	3.34	1,040	7,592

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 8

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to base of ore is about 42 feet. Adit length from rim to northeast of an elevation of 5,560 feet is about 420 feet. Length of 20° incline from northeast would be about 100 feet. Drifting distance from block 7 is about 110 feet. Ore is low grade.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 3 ore holes and 11 barren holes. Extension of the ore from the northwest lens is probable.

Summary of Reserves: 0.34 ton ore and 0.94 lb. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	--	--	--	--	--
Inferred Ore	1.1	0.14	1.08	280	784
Total	1.1	0.14	1.08	280	784

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 9

Date: August, 1952

District: Shiprock
Area : King Tutt Mesa
Locality: East Carrizo
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim: Begay No. 1 of E. Tapahonso
Owner: Navajo Indian Council
Lessee: Texas Mining Co.

Mining Availability: Depth to bottom of ore is about 50 feet. Adit length from the rim at elevation 5,560 feet is about 560 feet. Incline length at 20° from east is about 120 feet.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 1 ore hole, 5 mineralized holes, and 3 barren holes. Extension of the ore to the north is probable.

Summary of Reserves: 0.11 tons ore and 0.56 lb. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	—	—	—	—	—
Inferred Ore	2.3	0.26	2.30	120	384
Total	2.3	0.26	2.30	120	384

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I

Ore Block No.: 10

Date: August, 1952

District: Shiprock
Area : Oak Springs
Locality: East Carrizo
Township: Unsurveyed sec. 11, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim:

Owner: Navajo Indian Council
Lessee:

Mining Availability: Depth to base of ore is about 206 feet. Adit length from the rim to the south is about 6,000 feet. Low grade, thickness and depth make this orebody uneconomic under present conditions.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. Low vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 1 ore hole and 3 barren holes.

Summary of Reserves: 0.07 ton ore and 0.15 lb. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	--	--	--	--	--
Inferred Ore	1.3	0.11	0.15	70	154
Total	1.3	0.11	0.15	70	154

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I — Ore Block No.: 11

Date: August, 1952

District: Shiprock
Area : Oak Springs
Locality: East Carrizo
Township: Unsurveyed sec. 14, T. 29 N., R. 21 W., New Mexico, M.& B.L.

Claim:

Owner: Navajo Indian Council
Lessee:

Mining Availability: Depth to bottom of lowest ore is about 25 feet. Distance from rim at elevation 5,670 feet is about 50 feet.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 1 ore hole and 4 mineralized holes. No appreciable extension of the ore is likely.

Summary of Reserves: 0.25 ton ore and 1.25 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	--	--	--	--	--
Inferred Ore	0.7	0.25	1.64	40	200
Total	0.7	0.25	1.64	40	200

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I   Ore Block No.: 12

Date: August, 1952

District: Shiprock   Claim:
Area : Oak Springs
Locality: East Carrizo   Owner: Navajo Indian Council
Township: Unsurveyed sec. 14, T. 29 N., R. 21 W., New Mexico, M.& B.L.   Lessee:

Mining Availability: Depth to bottom of ore is about 31 feet. Low grade of ore makes exploitation uneconomic under present conditions.

Metallurgy: Carnotite type ore usually low in lime but in places may be over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits determined by 2 ore holes, 1 mineralized hole and 2 barren holes. Extension of the ore is probable.

Summary of Reserves: 0.4 ton ore and 1.04 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	0.8	0.12	1.03	100	240
Inferred Ore	--	--	--	--	--
Total	0.8	0.12	1.03	100	240

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I   Ore Block No. 13

Date: August, 1952

District: Shiprock   Claim:
Area : Oak Springs
Locality: East Carrizo   Owner: Navajo Indian Council
Township: Unsurveyed sec. 23, T. 29 N., R. 21 W., New Mexico, M.& B.L.   Lessee:

Mining Availability: Depth to base of ore is about 26 feet. Distance from the rim is about 40 feet. Thickness of ore will result in a high cost of mining. More tonnage is required to amortize the development work.

Metallurgy: Carnotite type ore usually low in lime but in places over 6 percent. High vanadium. Salt Wash sandstone.

Access: Thirty-three miles improved dirt road to Highway 666, thence seven miles to Shiprock, New Mexico.

Discussion: Ore limits are determined by 1 ore hole and 3 barren holes. Extension of the ore is probable.

Summary of Reserves: 0.25 ton ore and 1.8 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	—	—	—	—	—
Inferred Ore	0.7	0.36	2.47	40	288
Total	0.7	0.36	2.47	40	288

UNITED STATES ATOMIC ENERGY COMMISSION
GRAND JUNCTION OPERATIONS OFFICE
EXPLORATION DIVISION
ORE RESERVES BRANCH

ORE RESERVE STATEMENT

Project: East Carrizo I — Ore Block No.: EC 14

Date: August, 1952

District: Shiprock — Claim: North Canyon
Area : Oak Springs
Locality: East Carrizo — Owner: Navajo Indian Council
Township: Unsurveyed sec. 10, T. 29 N., R. 21 W., New Mexico, M.& B.L. — Lessee:

Mining Availability: Depth to bottom of lower ore horizon is about 95 feet. Adit length at an elevation of 5,855 feet is about 250 feet. The ore occurs in 2 horizons separated by a few feet of waste.

Metallurgy: Carnotite type ore usually low in lime but locally may be over 6 percent.

Access: Thirty-three miles improved dirt road to Highway 666, thence 7 miles to Shiprock, New Mexico.

Discussion: Ore limits are determined by 15 ore holes, 3 mineralized holes and 15 barren holes. Some extension of the ore limits to the north is probable.

Summary of Reserves: 0.33 ton ore and 1.31 lbs. U_3O_8 developed per foot of drilling for ore block.

	Thickness Ft.	Percent U_3O_8	Percent V_2O_5	Tons Ore	Pounds U_3O_8
Indicated Ore	1.5	0.20	2.54	1,150	4,600
Inferred Ore	—	—	—	—	—
Total	1.5	0.20	2.54	1,150	4,600